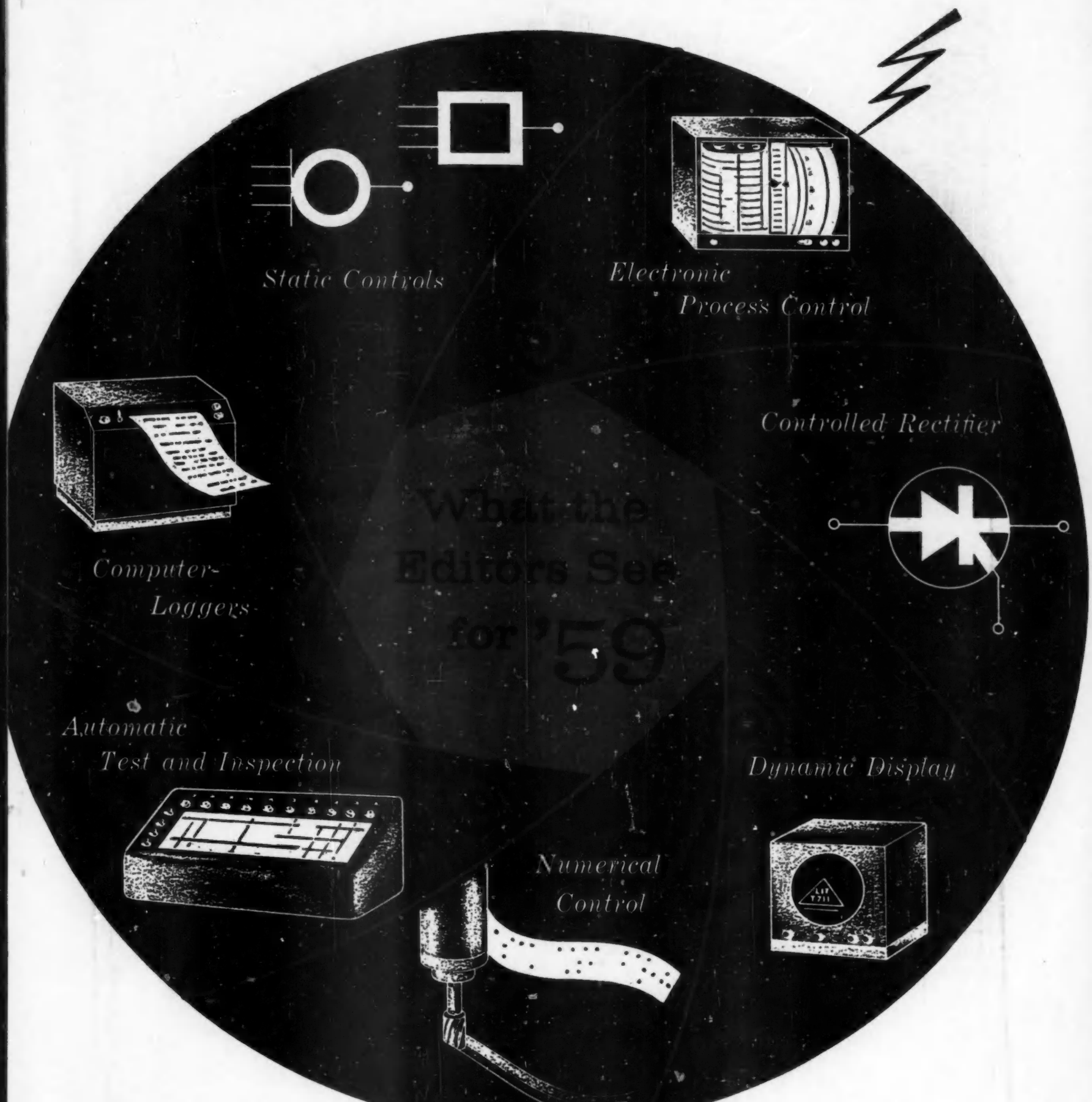
Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

60 Cents

JANUARY 1959



RE: Engineering
TO: Sales Dept.
RE: Sales Point

Al - An interesting point to pass along on our shaft encoders - We are using the LGP-30 computer to design the logic and the disc pattern for the encoders -

Wes

tough design problems solved with a computer

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Special units may be designed to fit your problems.

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CODE	MODEL†	Resolution Per Input Shaft Rev. (Counts)	Accuracy Over Full Range	Dimensions Diameter x Length
BINARY	7 digit	128	1 part in 128	2" x 2 49/64"
	13 digit	128	1 part in 8192	2" x 3 19/32"
	17 digit	128	1 part in 131,072	2" x 4 13/16"
	19 digit	128	1 part in 524,288	2" x 4 13/16"
10 BIT	10 digit	1024	1 part in 1024	4 3/16" x 1 1/4"
SINE-COSINE	*	*	1 count in total capacity	4 3/16" x 3 3/16"
BINARY CODED DECIMAL	0-2000	200	1 part in 2000	3 1/16" x 4 27/32"
	0-3600	200	1 part in 3600	3 1/16" x 4 27/32"
	0-20,000	200	1 part in 20,000	3 1/16" x 4 27/32"
	0-36,000	200	1 part in 36,000	3 1/16" x 6 3/8"
GRAY	8	256	1 part in 256	3 1/16" x 1 11/16"

†SPECIAL UNITS AVAILABLE

Precision gearing
Shaft Speed: 120 rpm continuous
Operating temp: −55°C to +75°C
Shock and Vibration: up to 15 G, 5 to 500 cps.

Life Expectancy: Function of lead current. For 13 digit unit @ 2 ma. per brush, life approx. 5×10^6 breaks or makes at approx. 120 rpm.

* 8 digits per quadrant plus the limit 1 plus polarity information. One turn of the input shaft generates 4 quadrants of information. Sine and cosine functions available simultaneously and independently.

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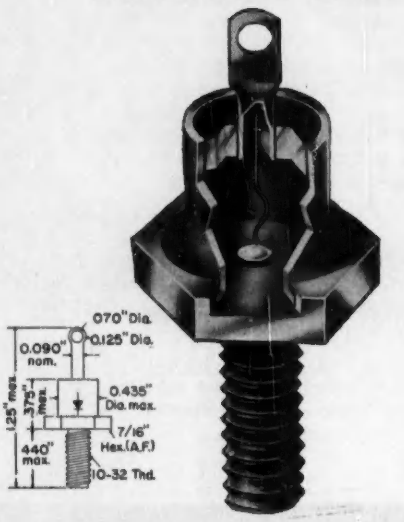
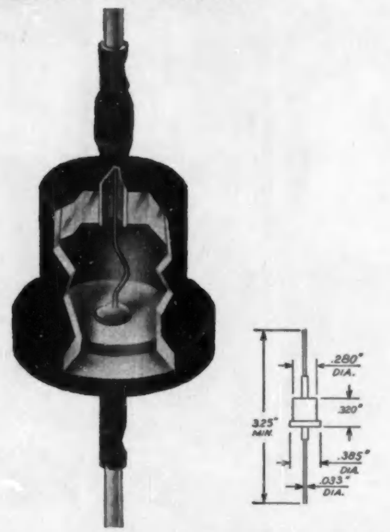
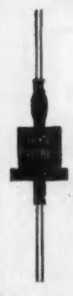


TYPE	Peak Operating Voltage −65°C to +165°C	Ave. Rectified Current 25°C	Ave. Rectified Current 150°C	Reverse Current (Max.) at Specified PIV, 25°C
	Volts	Amps.	Amps.	μA
1N253	95*	3.0	1.0*	10
1N254	190*	1.5	0.4*	10
1N255	380*	1.5	0.4*	10
1N256	570*	0.95	0.2*	20
CK846	100	3.5	1.0	2
CK847	200	3.5	1.0	2
CK848	300	3.5	1.0	2
CK849	400	3.5	1.0	2
CK850	500	3.5	1.0	2
CK851	600	3.5	1.0	2

1N253 through 1N256 available to MIL specifications *to +135°C

WIRE-IN-TYPE





TYPE	Peak Operating Voltage −65°C to +165°C	Ave. Rectified Current 25°C	Ave. Rectified Current 150°C	Reverse Current (Max.) at Specified PIV, 150°C
	Volts	mA	mA	mA
1N536	50	750	250	0.40
1N537	100	750	250	0.40
1N538	200	750	250	0.30
1N539	300	750	250	0.30
1N540	400	750	250	0.30
1N1095	500	750	250	0.30
1N547†	600	750	250	0.35

1N538, 1N540, 1N547 available to MIL specifications. †Same as 1N1096

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Control ENGINEERING

JANUARY 1959
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Continued on next page

Control
ENGINEERING

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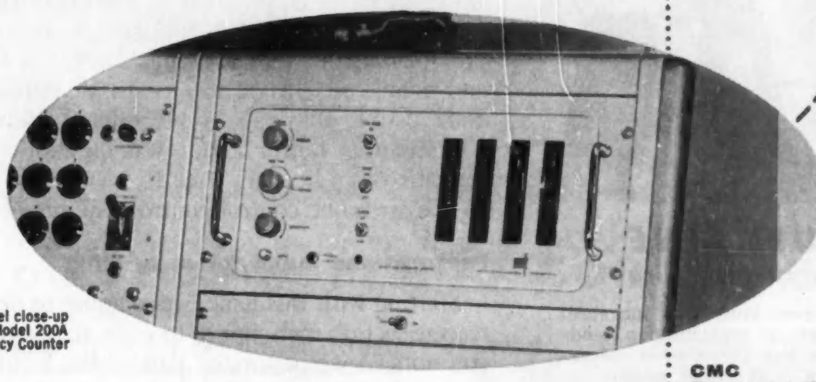
why h-g-b uses CMC electronic counting equipment

FOR RELIABLE FREQUENCY MEASUREMENTS



Control panel close-up showing CMC Model 200A Frequency Counter

Hanson-Gorrill-Brian, Inc., Glen Cove, New York, manufactures automatic data recorders for engine test stands, refineries, wind tunnels, etc. The Type 5 Data Master® shown above is a pressure logging device capable of scanning a number of pressures at rates up to 4 points per second, measuring them with an accuracy of ±0.25% and recording the data in digital form on punched tape, cards, etc. Frequency counter requirements for the Data Master® system demand extreme reliability, coded output, simple operation and rugged construction. To fill these requirements, the CMC Model 200A was selected.

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CMC makes 6 different models of frequency counters, frequency period counters and universal counter-timers in ranges from 0 cps to 220 kc and 0 cps to 1 mc and in price ranges from $425 to $1175. Three types of readouts are available: standard decade, CMC Inline-Inplane and Inline Nixie. Where counting and timing equipment is required, you will find a CMC counter designed to fit every conceivable application. Phone your local CMC engineering representative for a demonstration or write directly to the factory for complete technical information. Address Dept. 081.

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SHOPTALK

There's no substitute for experience

To bring you that little bit extra, CtE editors will go to almost any length. Last month, for example, while Associate Editor Lew Young was in Washington interviewing CAA Administrator James T. Pyle, the CAA chief told Lew that "he really couldn't do a story on air traffic control until he had obtained the pilot's viewpoint." Pyle offered to show CtE's news editor the problem first hand, and Young jumped at the opportunity.

The next night, when Administrator Pyle flew himself to Milwaukee in a twin-engined Beechcraft, Lew was sitting alongside in the co-pilot's seat. During the flight, 4 hours and 50 min nonstop, CtE's editor was indoctrinated into the problems of instrument flying, and got a flock of anecdotes and details on CAA's operations, air traffic control problem and possible solutions (and a flying lesson). Twenty min after landing, Editor Young was on another plane (commercial this time) heading back to New York. For CtE's report on the air traffic control controversy, turn to page 22.

Perforations make for easy filing

Starting with this issue, we're going to perforate the entire feature section each month to make it easy to tear out (maybe you noticed we perforated part of the features in November as an experiment). This makes possible easy filing of any editorial material with a permanent reference value. Let's hear what you think of it.

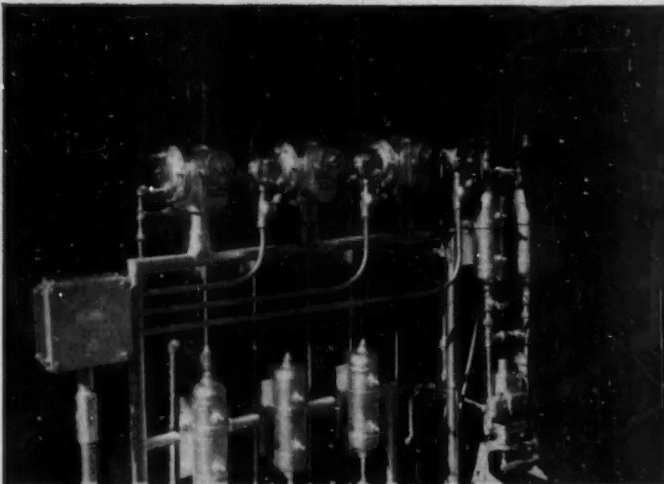
Automatic storage and retrieval

The editorial pages of CONTROL ENGINEERING have abounded with material on the automatic storage and retrieval of information; now we're moving into the analogous area of automatic storage and retrieval of physical items, i.e., automatic warehousing. A careful look at the field shows that the technology is available; economic justification is the stumbling block. To show what's possible, Author Marland (page 65) reviews five possible approaches, from a manually operated warehouse to a computer-controlled installation. It begins to appear that economic gains are possible. Outstanding examples of money-making automatic systems will be covered in future issues.

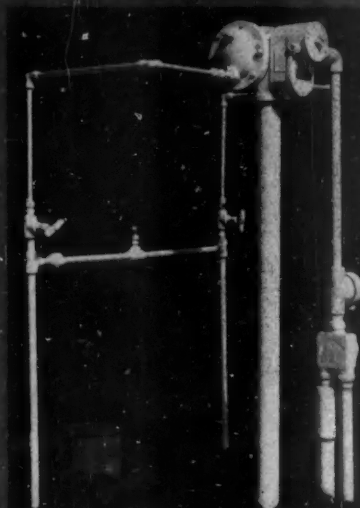
Coming next month

To whet the appetite, here's a sampling from next month's feature section: examinations of nonlinear static switching networks for four- and five-speed synchro systems, and of versatile hydraulic relays; a survey of automatic remote tank-gaging systems; some tips on how to survive in the systems business; how the Japanese automatically control a gear hobber; and more.

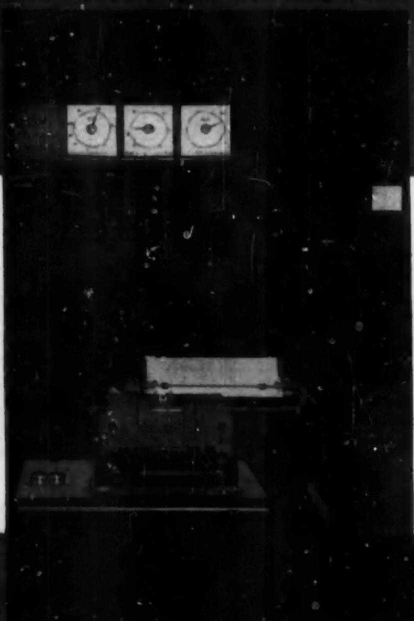
pressure and flow data



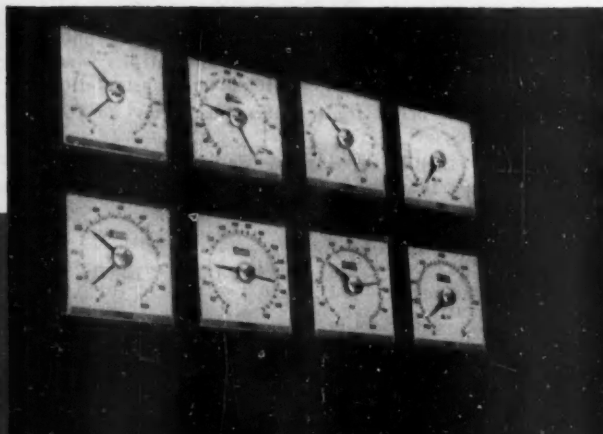
ElectroSyn flow transmitters at Service Pipe Line Company's pumping station, Drumright, Oklahoma.



ElectroSyn flow transmitters at Service Pipe Line's Blake Station (Washington County, Oklahoma).



Satellite data logging of pressures and flows of Drumright Station.



ElectroSyn flow and pressure indicators and digital encoders at Blake Station.

FEEDBACK

PROBLEM FORUM

The design of sequence-control circuits for machinery is the topic of this problem. It was inspired by a CtE reader who thought that he had a design procedure simpler than the procedure offered by a CtE author. Reader presents his procedure (for which he earns a little money) and author comments on the procedure (he, too, picks up some coin of the realm).

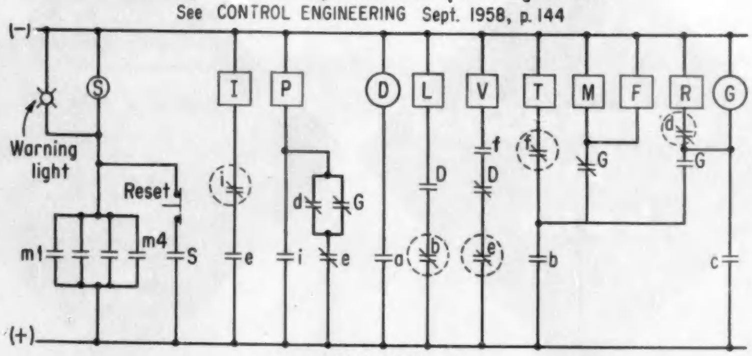
Problem Forum gets heavy reader traffic. Submit your problem, or your analysis of a problem solution presented in a feature CtE article. Others see it, and learn, while you earn a few bits. And when readers comment on your item, you learn, too. Ed.

To the Editor—

I enjoyed very much reading the September 1958 issue.

However, reading the first problem in the article, "Putting Logic to Work in Designing Distributed Program Control Systems", by Robert A. Mathias, I had a feeling that the use of Boolean algebra and the design logic charts were somewhat contrived. To argue my point, I designed, by trial and error, a circuit to suit the "Sequence of Operations for One Station" that appears on page 140. This circuit is shown in the attached drawing.

Complete memory and load switching circuit
See CONTROL ENGINEERING Sept. 1958, p. 144



INPUT DETAIL

i - Index signal
a - Clamp closed
b - Frame up in position
f - Transfer bar fully returned
c - Hole depth reached
d - Drill lead fully retracted
e - Frame down on transfer bar
D - 10 sec. delay relay S. M. F. B.
G - Memory relay

As you can see in this circuit, we need only one memory (relay) compared to the four required by Mr. Mathias' circuit. Moreover, under certain conditions, it is possible to eliminate one of the limit switches. Using different mechanical components, such as a pneumatic or hydraulic transfer bar actuator and a two-position solenoid valve, where we can maintain our input signals, further simplifications could have been achieved. The elimination of five contacts is shown in the drawing with dotted circles around them. If we don't need F for safety purposes, we can eliminate it altogether. Reason: order in design.

I believe that in designing a control circuit we have to follow certain principles. A few of them are:

1. The control circuit is an integral part of the machine that it should control. (Therefore, it should not be forced on the machine.)

2. Control components for input and memories should grow out of the design. (Therefore, they should not be forced on the designer; nor should they be assumed beforehand.) Quan-

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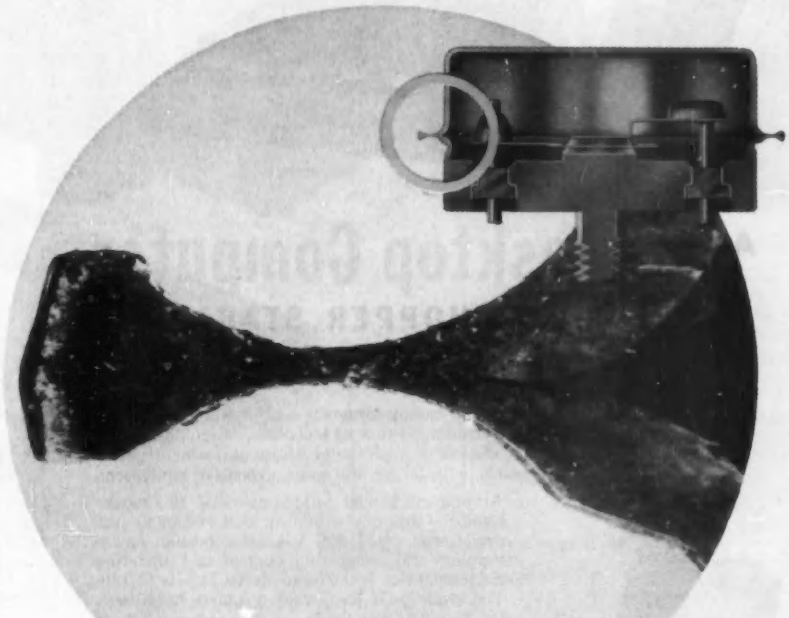

Photomicrograph (45X) shows circled area of cross section of Tung-Sol high-power germanium transistor cold-weld seal. Note absence of seam, indicating actual integration of copper molecules and a true, hermetic, copper-to-copper seal.

Once again Tung-Sol shows the way. Now, for the first time, Tung-Sol brings designers high-power germanium transistors with quality benefits of the advanced cold-weld seal.

The new Tung-Sol types feature a stud-mounted package and maximum collector current of 13 amps. Military environmental tests combine with the radioactive gas leak detection test to assure maximum reliability.

Technological advancements such as this keep Tung-Sol ahead of the field. For full data on the new high-power switching transistors . . . to meet any need with the latest in transistor design and efficiency, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

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tity, type, location, contact arrangement, etc., of control components should be read out of circuit drawings.

Gideon Halevi
Michael Flynn Mfg. Co.
Philadelphia, Pa.

Author comments

To the Editor—

Mr. Halevi is to be commended for his search for better chart and mathematical methods in design of control systems. I've found the methods outlined in my article useful to me. These are my comments upon Mr. Halevi's numbered remarks:

1. My examples are only examples, and not finished designs. I worked them from the beginning as new problems, which they were, using realistic conditions and restrictions.

I agree with Mr. Halevi that the control must be an integral part of the machine. Accordingly, only the initiation of input signals was used in the first example, since the exact termination time would be subject to the machine design. For purposes of the example, I did assume the signal termination to fall somewhere within the interval shown.

I began by examining possible memories needed by both machines and logic requirements (such as P in Figure 1 of the article). At this stage the experienced designer may be able to "scheme" the necessary memory functions compatible with the vagaries of his control comments and his machine being controlled. If many sequential states are required he may do well at this point to reduce states by some systematic method, such as the Huffman-Mealy one. This method is fairly involved (the reason for not going into it in the article) but may throw fresh light on the system requirements, eliminating redundancies and conflicts

2. The control components, of course, result from the entire system design. One of the systems requirements may virtually prevent using a certain type of control component, such as one with mechanical contacts, for example. Thus, the designer may have to build his control around contactless switch elements. And I agree that in many cases (if the control logic is not complex) much of the logic may be part of special input and output devices.

Mr. Halevi's circuit gives the simple functions, T and R, correctly. The other simple outputs of D, I, L, and V are not ON for the required intervals. His memory relay, G, does give

M correctly, but does not give the important signal *P* the correct start or finish. With two or three more memories he should be able to easily patch up his circuit to give the required outputs for the inputs given.

I think that what Mr. Halevi did was to modify the inputs to be ON for intervals that were best for the logic circuit, and not for what I considered to be the given input specifications. If my problem had also included the design of the machine, then by using the methods outlined in the article I, too, could have attained a more simple logic. Even if the design problem includes specifying when inputs should occur, I think that the chart and switching algebra methods can always help in reaching straightforward solutions by systematic methods.

R. A. Mathias
Carnegie Institute of Technology
Pittsburgh, Pa.

Corrects sigma value

To the Editor—

I noticed that the article by your Mr. Vannah entitled "A Control Earning Index" (CtE, August) uses 66.6, 95.6 (9.56 is a typographical error) and 99.7 for values of area under the curve plus and minus 1, 2 and 3 sigma. Most publications, including McGraw-Hill's *Quality Control Handbook* by Juran, and the Pickett Statistical Quality Control Slide Rule, give 68.3, 95.5, and 99.7 for those figures. Little difference, but I'm puzzled.

Robert A. Bennett
Arvada, Colo.

Thanks for the correction. We have checked against another reference and find that you are right. Ed.

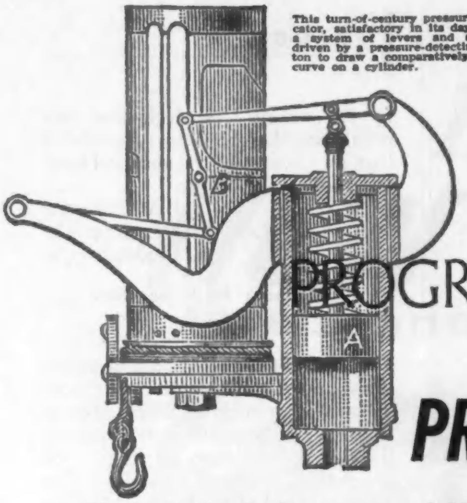
Computer is newsworthy

To the Editor—

We would like to point out a discrepancy that crept into the story, "Operating Guide Computer On-Line in Esso Refinery" (CtE, Oct. 1958, p. 22).

The story said "one newsworthy thing about this installation is that it represents L&N's entrance into the digital field". Actually, this marks L&N's entrance into the "digital computer field". L&N has been supplying digital data systems for quite a while; the first, a 30-channel simultaneous system, was delivered to NACA at Langley Field three years ago.

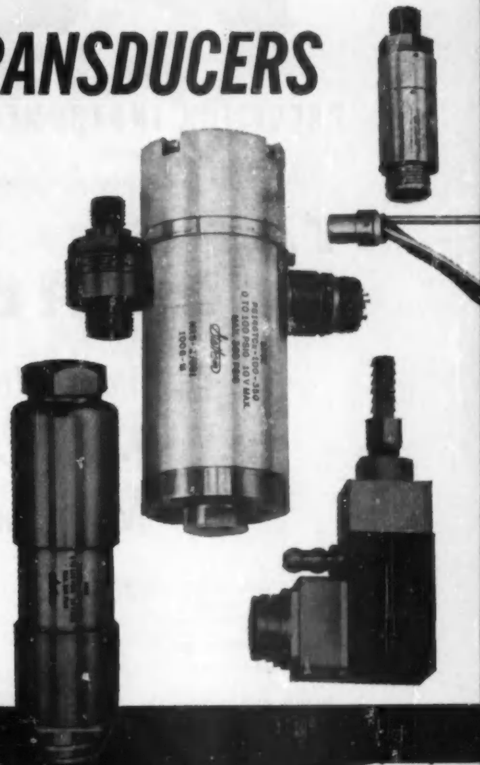
You will also be interested to know that we used a Giannini shaft-position-to-digital unit on the Esso job. One



This turn-of-century pressure indicator, satisfactory in its day, used a system of levers and springs driven by a pressure-detecting piston to draw a comparatively crude curve on a cylinder.

PROGRESS IN MEASUREMENT

PRESSURE TRANSDUCERS



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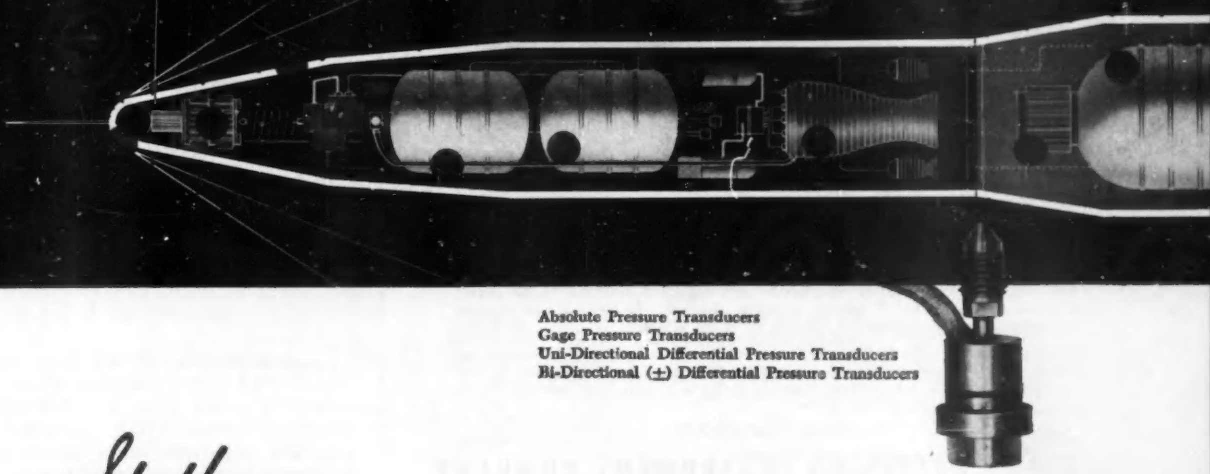

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J. M. Plummer
Leeds & Northrup Co.
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Feedback feeds on itself . . .

To the Editor—

Mr. J. E. Valstar in a letter published in the October 1958 issue asserts that one sufficient condition for nonlinearity of an integro-differential equation is that the coefficients appearing therein be functions of time (the assumed independent variable). This is, of course, not true. The offending phrase is capitalized in the quote below from the end of the second paragraph of the letter. ". . . or, if one of the coefficients is not constant but depends in value and/or sign upon one of the variables of the control system OR UPON TIME."

B. H. Kramer
American Cyanamid Co.
New York, N. Y.

. . . again

To the Editor—

In *Feedback* in the October issue of Control Engineering there appeared a letter clarifying the use of "nonlinear." In that letter the equation $o = Ai + B\int i\,dt + C\,di/dt$ is used and defined, where o is the output, *i* is the input and A, B, and C are constants. That this is a linear integro-differential equation is a true statement. This statement is then made:

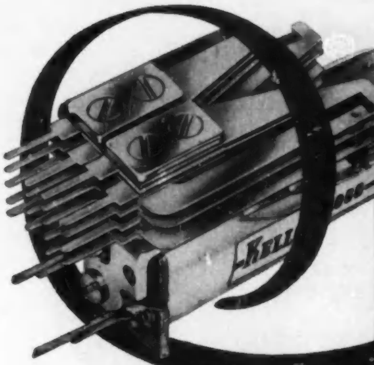
> "The equation becomes nonlinear as soon as one of the terms appears with a higher degree (squared, for instance), or if one of the coefficients is not constant but depends in value and/or sign upon one of the variables of the control system or upon time."

The very last two words, "upon time," should be deleted since $o = A(t)i + B(t)\int i\,dt + C(t)\,di/dt$ is merely a time-varying *linear* integro-differential equation and not a nonlinear equation.

Bernard S. Morgan, Captain USAF
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

Captain Morgan's closing paragraph is a very effective editorial comment: "To some analog computer users the idea that a time-varying equation is nonlinear sometimes arises because a multiplier or a function fitter is necessary in solving the equation. This may have misled Mr. Valstar." Ed.

KELLOGG'S NEW type "AK" telephone type direct current RELAY



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Alternative: Single or double microswitch
Standard terminals also available

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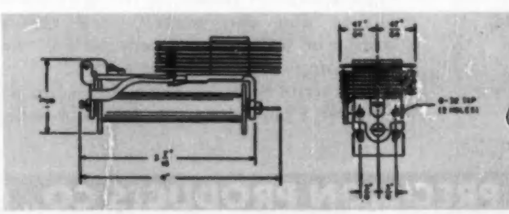

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Paul H. Savet

unmasks applications by analysis

When Paul Savet left France as she fell before the Germans in World War II, his passport was a roll of microfilm, his most important personal asset a keen mind. Now head of technical staff, missile guidance for American Bosch Arma Corp., Savet can look back on the escape with some equanimity, having found plenty of problems since to challenge his native analytic ingenuity.

Analysis is Savet's key to the solution of tough problems. A mathematician and engineer, he chides his professional colleagues for abandoning rigor for empirical approaches. While he recognizes that not all problems fall before the queen of sciences, he seems to blame any failure of mathematics on failure of imagination. He feels that a lesson is explicit in postwar experimenting with jet aircraft control. The control "reversal" that was learned about the hard way by test pilots of early jet craft was, Savet points out, analyzed mathematically by a Frenchman in the middle of the Nineteenth Century.

Engineer-mathematician Paul Savet was born in Rumania in 1907, educated in France. He took his first degree in electrical engineering, two advanced degrees in theoretical mathematics while working with the French Air Ministry as scientific adviser during the 'thirties. His PhD thesis, which he defended in the University of Paris in 1937, was a theoretical analysis of then-classified work in aeronautical control, the theory masking the practical application but setting an approach to engineering problems that Savet has always valued.

While in the ministry, Savet developed the pneumatic controls for the Planiol supercharger; it was among the first successful applications of servo systems. Savet found, incidentally, that keeping in mind electrical network feedback systems as an analogy helped in devising the system.

As the war approached, the French Underground urged Savet to flee—the Germans had marked him for his work in evaluating their capabilities. He heeded the warning, calling on his hobby of mountain climbing to help him through the rugged Pyrenees Mountains to Spain, and thence to Portugal and Gibraltar. There, he joined the British merchant fleet, became, of all things, a barnacle scraper.

After a complicated set of circumstances, not simplified by his lack of travel papers, Savet arrived in the United States. The roll of microfilm—it contained the essence of the work on the Planiol supercharger—clinched his entry; Fairchild Corp. thought it could use it to give its fighter plane, the P-38, an important altitude boost.

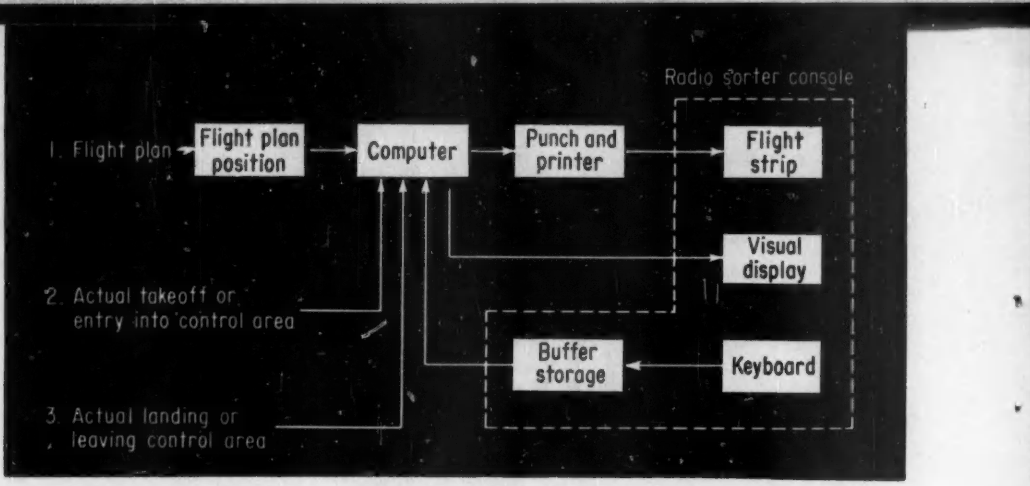
Savet's work with Fairchild, from 1941 to 1944, was followed by several years with Borg-Warner. There he studied the problems of applying control to supersonic aircraft. And he tackled the lubrication of jet engine bearings. His simple solution is still used: he let the fuel do the job.

After the war, Savet and four other B-W engineers went into business on their own, formed the Newton Co. (named after Sir Isaac Newton) in 1946. Eventually they found themselves in flight simulation.

Savet became chief engineer of the Newton Co. in 1949, then vice-president and finally president. He decided in 1951 that there were too many sleepless nights worrying about meeting payrolls and sold his share in the firm. He went to American Bosch Arma as head, Research Group. In 1956 he entered missile guidance work.

At Arma Savet has directed development of servo components and autopilots for the demanding missiles and aircraft field, and the development of inertial guidance systems for both the Titan and Atlas projects. One result of the latter work is that he has become interested in gyros, enough so that, as a member of the Board of Advisers of the Adelphi Research Center, he has developed a gyro course and from it a textbook that will be published by the McGraw-Hill Book Co. next summer. He keeps his interest in mathematics fresh by teaching a variety of advanced math courses at the Polytechnic Institute of Brooklyn.

Savet is married and has a son who wants to be a physician. At home in Westbury, L. I., just a few minutes' drive from Arma's Garden City facility, he turns from his technical activities (for which he holds over 20 patents) to botanical ones. An amateur organic gardener and experimental botanist, he has developed a new variety of tulip tree; two of its kind grace his yard. He insists his lawn is "95 percent crabgrass" and it may be; but it is there that he can often be found thinking about celestial mechanics or missile guidance.



System design of the GPL enroute data processing scheme.

Grumbles Over Air Traffic Control

Is the new Federal Aviation Agency buying a data processing system that's obsolete—even before it's installed? That's what some computer men think. First application of systems approach to air traffic control has not won unanimous approval. Here are some of the pro and cons.

For the first time, a U.S. government agency, the new Federal Airways Agency (FAA) is applying the systems approach to air traffic control instead of attempting to patch up the traffic handling techniques on a hand-to-mouth basis. FAA has launched a five-year program to equip the air traffic control system with $1.8 billion worth of special-purpose computers, display equipment, automatic data links, navigation equipment, and long-range radars.

But not everybody completely approves the approach. The complaint has been raised that FAA's crash program will leave the air traffic control system—grossly inadequate today—woefully behind the rapidly growing air traffic requirements of the 1960's. The heart of the controversy stems from FAA's decision to automatize today's procedures rather than attempt new concepts, the reluctance of operation-oriented controllers to accept radical technical innovations, and the weakness of FAA's technical staff.

Actually, there are two different jobs to do: first, bring the present overloaded system up to a capacity that can handle today's traffic; and second, expand the capabilities of the up-to-date system to keep pace with the continuing increase in traffic. Today, most traffic is uncontrolled; a large segment is controlled only in poor weather. A lot of people feel that future traffic must be controlled at all times and under all weather conditions.

• **The enigma of general aviation**—On an average day in the U.S., over 200,000 flights are completed by aircraft of all types—military, commercial, and private. Of this number, just over 10 percent—22,500—use the present air traffic control system. The rest fly visual flight rules (VFR), relying on the pilot to keep his eye peeled for other traffic.

A major problem of air traffic control is how to regulate and direct the aircraft of general aviation – private planes of all types and sizes—which constitutes well over 80 percent of all airplanes in the U.S. Traditionally, aircraft of general aviation has been able to go where it wanted, when it wanted, as long as the pilot followed the rules of the road. And many of these planes carry only a minimum of instrumentation: altimeter, compass, and radio. Yet to fly under traffic control requires special instrumentation and considerable pilot skill.

To solve the control problem, the new agency is putting a lot of its eggs in one basket, counting on the performance of a semiautomatic data processing and display system developed by General Precision Laboratories, a division of General Precision Equipment Corp. Critics of this approach say it is obsolete and outmoded already—even though the first unit is still under construction—because it is based on the out-of-date concept of handling air traffic almost exclusively along airways. What's really needed, these critics say, is a new concept of how to organize and control air traffic over the entire air space.

• **The overall plan**—The GPL system got its start under FAA's predecessor, the Airways Modernization Board. An organization to coordinate air traffic control activities was proposed in the Curtis report (a document prepared by a committee headed by Eastman Kodak's Edward P. Curtis, who had been appointed assistant to the president for aviation), which has become the blueprint for modernizing aviation facilities. Established in August 1957, AMB lost no time getting a three-phase program under way. FAA, which replaced AMB on November 1, has continued it. The plan:

▶ Phase I – in-service improvement of the present air traffic control system, using equipment in place and on procurement.

▶ Phase II—application of existing technology to solve the air traffic control problem. AMB planned a five-year program to be completed by 1963, to handle traffic until 1975.

▶ Phase III—continuing long-range research and development.

• **Mechanization by CAA**—Phase I of AMB's program has been handled by the Civil Aeronautics Administration (whose responsibilities were to be absorbed by FAA on Dec. 31, 1958). CAA, which had been inert technically until a new administrator, James T. Pyle, gave it a shot in the arm in 1956, has placed orders for new airport surveillance radar and long-range radar for en-route surveillance.

Pyle encouraged the mechanization of flight progress strip preparation in Air Route Traffic Control Centers (ARTCCs). When a pilot files a flight plan for a trip under instrument flight rules (the only flights making use of air traffic control facilities), the

center prepares a flight progress strip for every checkpoint he will fly over. On a trip from Washington to Milwaukee, for example, the plane flies over 12 checkpoints. A trip from New York to Los Angeles requires 35 to 40 strips, depending on the route.

Preparing flight strips is a bookkeeping job that takes up to 75 percent of a controller's time. New York's air traffic center at Idlewild Airport, for example, makes out 10,000 flight strips a day. The controller and his assistant must compute an estimated arrival time for the plane at each checkpoint, study the strips to determine if there is a conflict between flights, and when a pilot drops behind or moves ahead of schedule, correct the strips.

Just this fall, CAA started using high-speed computers to do the computation and printing of flight strips. An IBM 650 RAMAC has been operating at the Indianapolis ARTCC since September. These machines compute estimated arrival times, search a memory for possible conflicts with other aircraft, then print out strips.

• **The five-year plan**—AMB's (and now FAA's) five-year program went well beyond what CAA was doing. It incorporates six main facets:

▶ data processing and display—a system to receive flight plans, compute estimated times of arrivals over fixes, detect conflicts, revise estimated times of arrivals from position reports, schedule landing and outbound flights, display computed and radar position, supply a legal record, transmit known aircraft positions to air defense centers, warn controller of expected progress reports, and track in three dimensions—all automatically.

▶ airport improvement—studies are aimed at measuring runway, taxiway and ramp utilizations, analyzing lighting and markings, developing high-speed turnoffs to decrease runway occupancy time.

▶ automatic communications—development of equipment to automatize all routine air traffic control communication—including position and altitude reporting, clearance requests, clearances, and traffic control orders.

▶ radar (beaconry)—Major objective is to develop a three-dimensional terminal radar for use at airports. Other efforts are aimed at integrating radar with automatic data processing and display equipment and developing improved radar beacons for installation in aircraft. Such a beacon would identify an airplane when the plane was hit by radar.

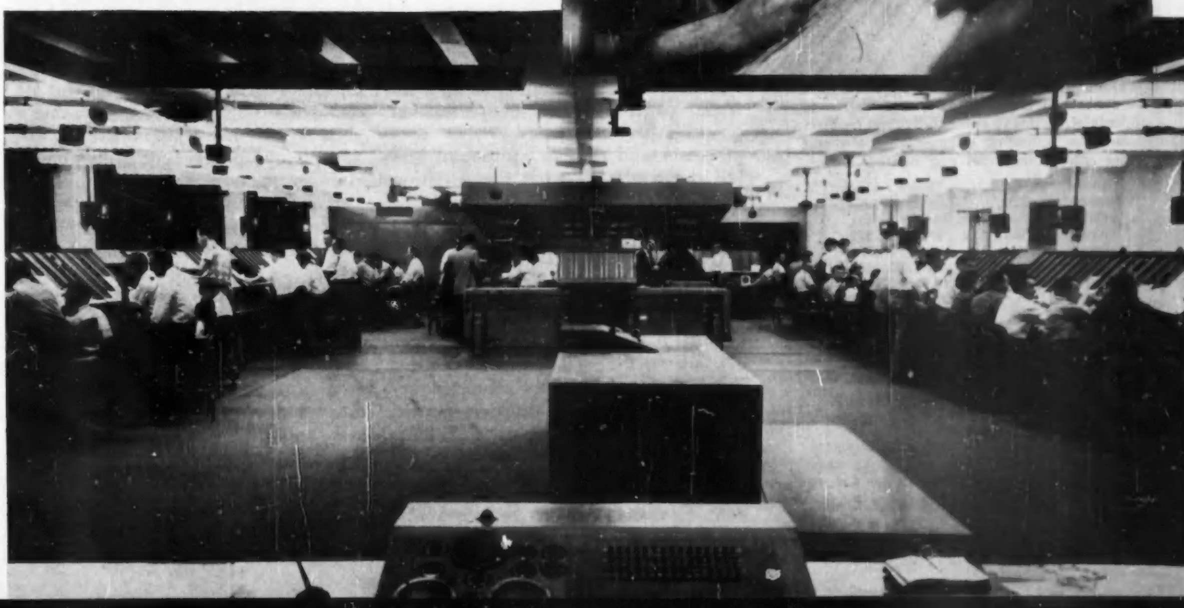
▶ navigation—chief activity is defining future navigational requirements for aircraft. Two types of techniques are being evaluated: self-contained equipment such as doppler radar, inertial guidance and dead reckoning gear; and complementary use of self-contained equipment with radio navigation tools, including hyperbolic navigation, radar corrected, and so-called "R-θ" systems.

▶ cooperation with air defense—the air traffic data processing system is to be modified to permit: control of a conflict-free initial scramble of fighter aircraft, automatic computation and transmission of outbound data to the air defense direction centers, automatic reception of air defense data, and automatic transmission of up-to-date flight progress data of civil aircraft to the air defense centers.

Early in its career, AMB decided the data processing system would have to be the heart of the mechanized air traffic control system. It issued invitations to bid with some strange reservations: 1) there was to be no development work even though this was the first such system ever built for air traffic control, and 2) the equipment was to be completed and ready for testing by January 1959—an incredibly short schedule.

Having divided the program into

New York's Air Route Traffic Control Center, photographed during a calm moment, handles as much traffic as any ARTCC in the country. Radar scopes, which help the center sequence aircraft into airports for landings, are in the middle of the room. Around the perimeter are boards of data flight strips. In bad weather, ARTCC activity looks like a combination of chaos and bedlam, with controllers shoutinig back and forth as they pass aircraft flights from one sector to the next, communicate with aircraft, and keep in touch with the airiport tower controls. Responsibilitiy for air safety is etched on controller's face (at right) as he studies flight progress strips, looking for possible conflicts.



. . . the biggest problem of air traffic control—how to organize traffic—has never been properly studied . . .

an enroute problem and a terminal problem. AMB awarded the enroute phase to GPL in February 1958 ($4,-272,484) awarded the terminal portion to GPL, too, in June ($3,971,963). Although the GPL system has been tagged an experimental one—recent plans are to evaluate it thoroughly at FAA's Atlantic City National Aviation Facilities Experimental Center with both simulated and live flights—FAA plans to use some form of the GPL system in actual control.

Lt.-Col. Carl B. Fisher, an Air Force officer who is serving as acting technical director of FAA's Bureau of Research & Development, guesses that at least 10 installations of the GPL system will be made at ARTCCs throughout the United States by 1963. He says they'll have sufficient capacity to handle traffic growth up until 1975, based on estimates incorporated in the Curtis report. Fisher assumes that not all aircraft will use air traffic control facilities.

GPL's present design should be able to receive 600 flights per hour; FAA hopes to improve it to handle 1,000 per hour.

But not everybody shares Fisher's optimism. For example, Lincoln Laboratory's David Israel (an MIT engineer who has closely followed air traffic control since 1949 and who has been working on the Air Force's air defense project SAGE since 1950) believes: "The chances of getting the GPL system to a point where it can be installed and evaluated within two years are slight. Chances that it will be used throughout the country are even more remote."

• **GPL systems: pro and con**—R. A. Finkler, GPL's deputy program manager for engineering, says the GPL system has been designed so that air traffic control will be implemented on an evolutionary basis. The data processor and display equipment will tell the controller what the situation is, what can be done to clarify the situation, but it leaves all decision making up to the controller.

The heart of the GPL enroute system will be a special-purpose transistorized computer, a binary-coded, decimal machine. Librascope, a sister division in General Precision Equipment, is building the computer because GPL itself has little computer experience. The machine will have file access memories on magnetic drums. Each drum—total capacity of the machine is up to 16 drums—can maintain 1,000 records and 1,000 duplicates; each record contains 64 characters, each character seven bits. In addition, the machine will have a 4,000-word core memory. Each word will contain eight alphanumeric characters of seven bits.

Operationally-oriented people, a reference to the controllers who must use this equipment, still exhibit serious reservations about the reliability of electronics. Their major concern is what happens to air traffic if the computer makes a mistake, or even worse, breaks down.

To allay fears of the former, the machine will have extensive checking facilities. All data transfer units will be parity checked; the computer will have dual arithmetic units to assure correctness of operations. In case of a computer breakdown, the enroute system will have a complete standby machine. Other safeguards: the buffer storage is duplicated and all magnetic drum files are duplicated.

• **Wanted: a new concept**—One of the key design criteria of the GPL system is that present procedures of air traffic control must remain unchanged. The avant-garde of air traffic control, familiar with the real capabilities of new data processing equipment, feel that an entire new approach should be attempted. They argue that the present system is over 25 years old, has grown like Topsy, and has been patched and mended on an emergency basis since the end of World War II. They claim that the biggest problem of air traffic control—how to organize air traffic—has never been studied properly.

Until this fundamental question has been resolved, they say, no air traffic control system, will really do the job. And the problem is not an easy one to solve. The main argument of this group: computers not only permit you to mechanize procedures, but they also enable you to do things differently—frequently easier and better—and handle situations not being handled today.

• **Flight strips to stay**—The GPL system will continue to use flight progress strips for backup data. Each line of strips on a GPL console will have its own printer, which will ride up and down a row, printing out flight strips and updating the strips as new information is received. Lincoln Laboratories' Israel (who discussed the short-

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SC-18-1	0-18	0-1	.02	.2	8¼"	4 5/32"	13⅝"
SC-18-2	0-18	0-2	.01	.1	8¼"	4 5/32"	13⅝"
SC-18-4	0-18	0-4	.005	.05	19"	3½"	13"
SC-36-0.5	0-36	0-0.5	.08	.8	8¼"	4 5/32"	13⅝"
SC-36-1	0-36	0-1	.04	.4	8¼"	4 5/32"	13⅝"
SC-36-2	0-36	0-2	.02	.2	19"	3½"	13"
SC-3672-0.5	36-72	0-0.5	.15	1.0	8¼"	4 5/32"	13⅝"
SC-3672-1	36-72	0-1	.08	.8	19"	3½"	13"

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  0.1% or 0.003 volt for load changes 0 to maximum (whichever is greater) at any output voltage in the range minimum to maximum.
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*Two units mounted in Rack Adapter RA-2

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- Continuously Variable Output Voltage. No voltage switching.
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ORDERING INFORMATION:
Units without meters use model numbers indicated in table. To include meters add M to the Model No. (e.g. SC-18-1-M).

*Rack adapter for mounting any two 8¼" x 4 5/32" units is available. Model No. RA2 is 5¼" high 19" wide.

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comings of current air traffic control efforts at a recent Radio Technical Commission for Aeronautics meeting), feels that "requiring the future air traffic system to be coupled closely to paper flight progress strips is unwise, unnecessary, and restrictive on the design of the future system."

Controllers, on the other hand, insist they must have the makings of a manual system in case the entire computer facility goes out of business. Flight strips, they emphatically declare, are perfect for this.

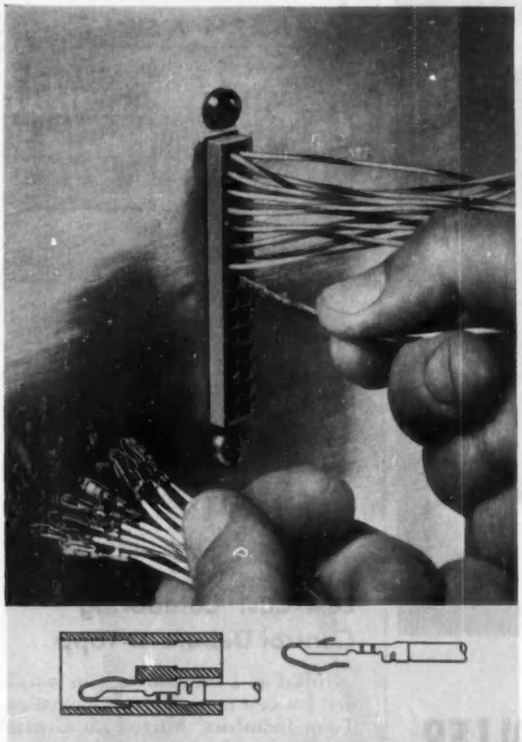
FAA has now ruled against an all-electronic display, citing safety and objections of controllers as the main reason. But a bigger problem, which FAA is not ready to admit, is that nobody is sure just what information the controller has to have and what form it should be in. The GPL system will use some electronic display. One plan in the works would provide each console with a conflict detector which will use the Stromberg-Carlson Charactron tube to display conflicts in the enroute system. A second involves a standard radar display to depict what's happening in the center's area.

• **Long lead time**—Another argument for—and against—a brand new concept is the time it will take to develop such a system. Basing an estimate on how long it took to develop SAGE, Israel guesses 10 years. His schedule leaves two to four years for research and development, two to four years for construction and evaluation of a prototype, and two to four years for system production, installation, training, and commencement of operation. That's why he feels work on a truly advanced system must start immediately. He feels the GPL system is only a stop-gap—and may not even be that.

FAA says that it cannot wait that long for a significant improvement in air traffic control system capabilities. Even with the improvements brought about by CAA's short range, brute force approach (CAA doubled the system's capacity in a year), U.S. air traffic control system lags way behind air traffic.

Who's right won't be decided until FAA finishes testing the first GPL system, due to arrive at Atlantic City around June. FAA has ordered a $1,877,453 simulator from Aircraft Armaments to help test it. If FAA's concept is right, the air traffic control system seems set until 1975. But if the new agency is wrong, the continuing snarl in air traffic could well wreck aviation's progress.

—Lewis H. Young



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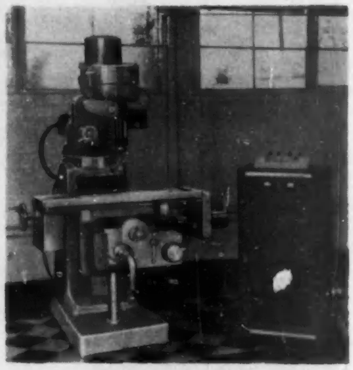

Micro-Path control applied to Gorton Mastermill equipped for three-axis control.

Low-Cost Contouring Control Debuts at Topp

Billed as a breakthrough in simplified low-cost machine-tool automation, Topp Industries' Micro-Path Control System—a numerical control that combines both point-to-point positioning and contouring—drew a full house when a commercially available model was unveiled in November. Most unusual aspect of the demonstration of the system, first described in CtE last February (page 108), was the cost: from $12- to $15,000.

This price tag is competitive with most point-to-point systems; but it is only a third as large as that on the lowest-priced contouring control systems, a tenth of the cost of many others.

Secret behind the low cost is the fact that the system needs no computer to place the program on the magnetic tape which runs the control. Instead, a controlled slide moving through the required motions records position data on the tape. (It is also possible to prepare the tape away from the machine by using a Topp recording table.)

• How it works—A positioned controller is supplied for each controlled axis of the machine. The operator can direct slide movement and set feed rate in response to the direction and amount of movement of the control. A toggle switch is used to select either high or low feed range.

The system, being built by Micro-Path, Inc., a division of Topp Industries, can be applied to a new machine tool at time of manufacture, to an existing machine in the field, or to a special machine tool.

Stratascopes

. . . trace coal seams and guide automatic coal-mining machine so that operator can stay above ground.

A remote-controlled mining system that will permit men to mine coal without going underground is in final commercial development at the Joy Mfg. Co. The idea originally developed by the Union Carbide Olefins Co. has been tested with a prototype machine which has operated for several months in the mines of the Peabody Coal Co. Joy expects to be able to market the machines in 18 months.

One of the key problems in building the automatic miner was equipping it to determine where the coal seams go. Underground, the seams wander up and down. Since the machine takes up the entire space it digs, there's no room for a "guide". Yet, without some sort of guidance, the machine will stray from the coal seam.

To solve the problem, designers put a pair of "sensing teeth" on the head of the mining machine. Called stratascopes, these teeth are spring-loaded, operating under a compression that varies with the resistance offered by a coal seam.

The stratascopes locate "bone coal", which appears as a layer in every coal seam and is harder than average coal. The bone coal layer stays approximately in the same position relative to the stone roof and floor of the coal seam no matter how crooked the seam might be.

The stratascopes are connected to oscilloscopes in the control room above-ground. When these teeth first hit the hard bone coal, the impact appears on the 'scope as a blip. The operator notes where the blip occurs and then controls the direction of the machine through hydraulic jacks to keep the blip in the same position. If the operator sees the blip at 10 o'clock, the blip stays at 10 o'clock as long as the machine follows the coal seam.

If it wanders, the operator can adjust the machine, from above ground, by actuating a hydraulic jack to raise or lower the cutting head. The head is pivoted on the main body of the miner.

The mining machine automatically loads coal into a heavy-duty continuous transport system that follows the machine into the mine and delivers the coal to an outside station.


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Model 1472
4" x 1.5" x 2.7" 2 Watts
Model 1466A
6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out
SUB-CARRIER OSCILLATOR.
Model 800C — 1.5" x 1.9" x 2.49"
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WHAT'S NEW

Improving Gas Transmission

High-speed telemetry system runs new peak period gas compressor station. It's the first step in widespread acceptance of sophisticated controls.

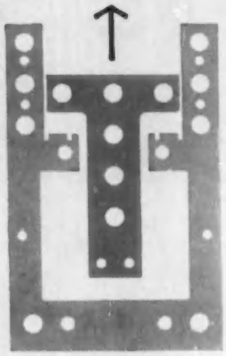
At Texas Eastern Transmission Corp.'s natural gas compressor station No. 27 outside Linden, N. J., one day in November, an intake valve on the main line spun open, a discharge valve whirled open, then a large-size reciprocating compressor engine started up, gradually was brought up to speed. What made this happening unusual was that nobody was in the station at the time. All operations of putting station No. 27 on the line were controlled from a branch station at Lambertville, N. J., 50 miles away.

One of the first applications of remote control in natural gas service, this installation was noteworthy for another reason, too. It was the start of an extensive program to use sophisticated control in natural gas distribution. Some typical plans: Texas Eastern will place at least four other remotely operated stations in use during the next year; it is studying the possible use of electronic computers to control the input of gas at the source end of the transmission line, much like an electric utility uses an economic dispatch computer to regulate generating. And Texas Eastern's chief of communications section, F. Vinton Long, has plans to develop a digital demand device that will meter flow at the delivery end of the line, correct the gas for temperature and pressure, and print out a result (instead of an area curve, which has to be measured and then computed by hand).

The Linden station is designed to operate intermittently, at peak periods of demand for natural gas, thus lending itself to remote operation. The station uses a high-speed telemetry system designed by Control Corp. of Minneapolis. Instruments in the pneumatic system were supplied by the Bristol Co.

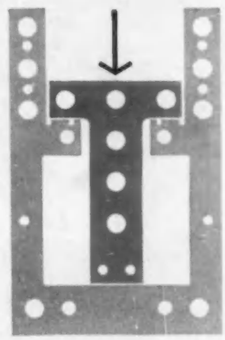
High-speed telemetry was required so that the branch station at Lambertville could detect surges instantly and watch rpm of the compressors, a key variable for control. The remote instrumentation also controls the opening and closing of line valving (main valves are gas-operated and equipped with limit switches), the operation of

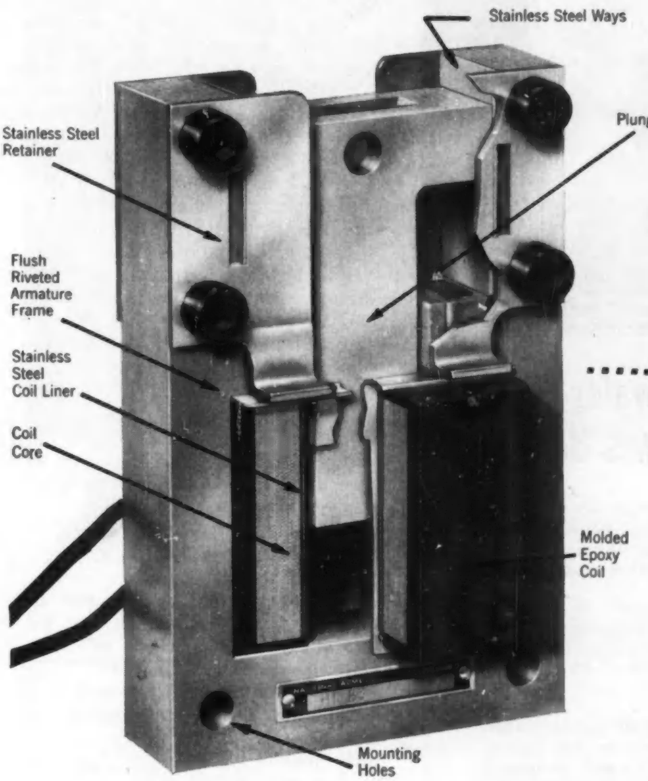
SOLENOID CHATTER ELIMINATED.....



.....

with the NEW NAMCO "H"-Series Solenoid





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Its noiseless holding operation permits solenoid applications never before considered practical. The usual chatter and clatter in the closed position is eliminated by a unique design that provides a positive three-point contact in the "holding position." Add to this Namco's stainless steel ways that provide improved performance and longer life; superior electromagnetic qualities, and the result is a *silent performer* you can't afford to overlook.

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CIRCLE 28 ON READER-SERVICE CARD

the engine driving the compressor (engine controls normally manipulated by station operators were replaced with solenoid action of the compressor), and an alarm system that warns of off-normal conditions, including the detection of fire.

Weakest link in the control system, says Communications Chief Long, is the communications. Station No. 27 receives its orders over telephone lines or microwave radio. One reason for using both is to get operating data on which one performs best technically and economically for Texas Eastern's future remote control installations.

Cement Plant Orders Computer

First installation of an electronic computer for process study in the cement industry will be at the Oro Grande (Calif.) plant of Riverside Cement Co., a division of American Cement Corp. The unit, an RW-300 built by Thompson Ramo Wooldridge Inc., will guide the operation of a mechanized rock blending facility. The computer will also provide information to guide quarrying operations.

For the present, the computer will do no control; however, it will collect and analyze data needed in planning automatic control systems for the cement manufacturing process. This means indicating required quarrying and stockpiling actions, keeping track of the amount, chemical composition, and point of origin of thousands of tons of rock and other raw material, and periodically calculating how much of what kinds of materials should be added to the pile to obtain the proper proportion of ingredients.

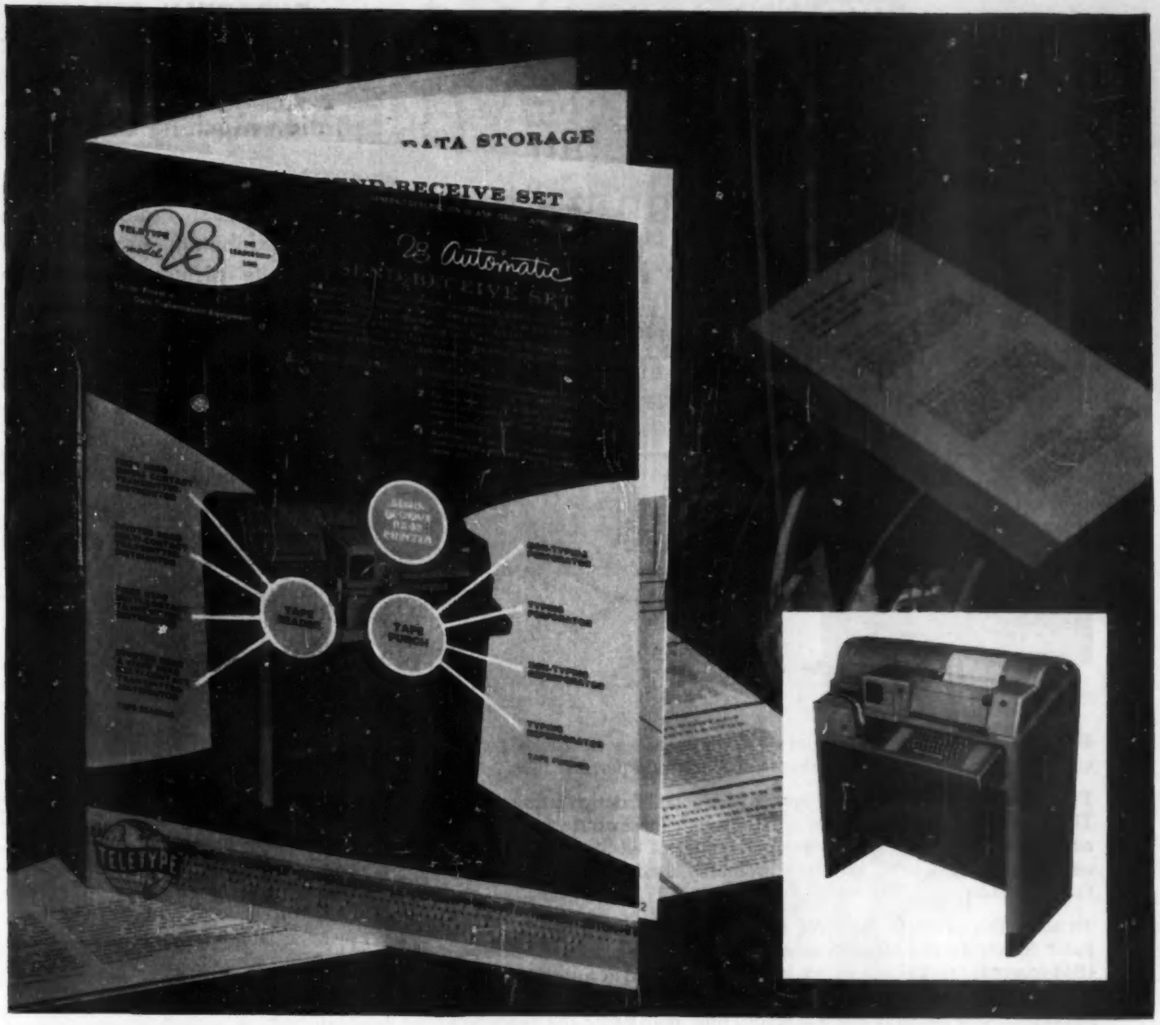
Analysis of rock samples will be made by x-ray spectrometer and fed into the computer, which will then perform necessary calculations.

The computer will also serve as a data logger, providing a continuous record in the plant's rotary kilns of such variables as temperature, fuel gas, gas flow, and rotation speed.

The system, estimated to cost $130,000, is expected to be installed in the spring of 1959.

•

"Liquid flywheel" for controlling space craft has been invented by General Electric engineer Robert P. Haviland. The apparatus uses a hoop-like arrangement of pipes through which a liquid is pumped at varying speeds. Changes in the liquid determine the force applied in one direction.



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Italian Machine Control

. . . faces tough foreign competition. First Italian Machine Tool Exhibition provided an up-to-date picture of the state of the technology in that country.

MILAN—

Italy's first machine tool exhibition was held mainly to make Italians a little better acquainted with Italian-made machine tools. So far, Italy's mechanical industry has found the grass greener on the other side of the fence, importing more machine tools than purchased from domestic manufacturers. In 1957, for example, imported machine tools took 59 percent of Italy's market.

The annual Italian production of machine tools amounts to $54 million, but over half of this is exported. The Italian market itself absorbs about $54.6 million a year of all kinds.

There are almost 250 machine tool builders in Italy, of which only five or six build heavy machines. Major figures include Fiat Co. of Modena, concentrating on drilling and boring machines, Zocca of Como, concentrating on grinding machines, Olivetti of Ivrea, producing grinding, plano-milling, boring, and drilling machines, Innocenti Co. of Milan, concentrating on heavy machinery such as plant rolling mills as well as milling and boring machines, and Maxnovo, copying lathes.

• **Social blocks**—The future of the Italian machine tool industry, as seen by Italian machine tool builders, does not look rosy. From the technical point of view, there is an obvious resistance to automation, owing to the social and moral repercussions that would stem from such a trend in a country rich in manpower and having one of the highest unemployment rates in the world. This explains the absence of foreign numerically controlled machine tools at the exhibition. Any effort in highly automated equipment by Italians would be aimed at export. Besides, any initiative to improve the industry technically calls for capital investment in common laboratories and research, a thing to which most machine tool manufacturers lend a deaf ear. The result is that the largest firms have their own laboratories and research centers, the smaller firms have nothing.

Market-wise, in 1957, six out of

every 10 machine tools sold in Italy were foreign made—with Germany heading the list of exporters to Italy. The situation is expected to become worse as the common European market takes effect and customs tariffs are lowered. This is already being felt in spite of the fact that for the first half of 1958, Italian machine tool manufacturers had won 70 percent of the domestic market, compared to 41 percent for all of 1957, while exports had remained fairly constant.

At the Milan show, 529 exhibitors displayed 2,200 machines weighing an aggregate 6,300 metric tons. Italian industrialists seemed willing to look at them; attendance went over the 30,000 mark, although only 20,000 was expected.

Featured were machine tools of all sizes, from accessories to giant plano-milling machines.

Quite noticeable was a wider use of automatic cycles (including automatic loading speed and feed preselection, servo-controls, positioning drums, servomechanisms and electromagnetic or electrohydraulic clutches). But numerically controlled machine tools were conspicuous by their almost total absence.

Maxnovo Meccanica di Precisione S.p.A. of Novara, Italy, was the only machine tool manufacturer, including domestic and foreign manufacturers, to show a punched card controlled machine. Its exhibit: a Profilomatic Model. AB copying lathe with "Telephotomation" card control.

• **Telephotomation**—The automatic cycle of the lathe is controlled by Maxnovo's Telephotomation system, employing a rotating punch card to set and control the various stages of the cycle. By substituting a new punched card regulating the nibs on the timing disc, a cycle is obtained for a different part. The system uses photoelectric cells to read the punched cards. And it can be applied to most types of machine tools.

Here's how it works. A dial on a spindle, which can be indexed to any of 12 positions by a mechanism within the control cabinet, has 12 radical rows, each of six holes. This dial is covered by a paper disc with printed circles over the hole positions. Holes are punched in the circles at positions that correspond to the sequence in which the various machine movements are required. At one side, the dial is covered by a light box, which can be swung back.

This design by Maxnovo—considered a pioneer in Italy's machine tool industry—is the only numerically

controlled machine tool in production in Italy today.

• **Numerical control users**—Olivetti Co. of Ivrea, and Fiat Co. of Turin—automobile and aircraft manufacturer—are the only Italian companies known to employ numerically controlled machine tools. Olivetti is using two punched-tape-controlled milling machines to make typewriter and calculating machine parts. The control system is Olivetti's own. Fiat is reported to have a Cincinnati punched-tape-controlled skin miller.

• **Automatic inspection**—Only one Italian manufacturer – Apparecchi Elettronici Marposs of Bologna – exhibited machine-tool automatic inspection equipment.

Marposs manufactures a wide range of automatic inspection equipment that can be mounted on grinding machines, the work bench, or in the inspection room to check mass or batch production. This equipment uses a "finger lock" to check any surface and correct irregularities.

Fingers in a number of shapes covering various operations on the machine (checking internal diameters, internal grooves, outside diameters, and outside surfaces; measuring keyed pieces, controlling thicknesses, etc.), are applied to a single or a double contact measuring head. An electronic set receives the signal from the measuring head and amplifies it so that the measurement is scaled.

Test equipment includes precision comparators for internal, external, and centerless grinding machines, measurement and control devices for surface grinding, dual control comparators for selective comparative machining, apparatus for selective assembly, precision comparators for bench use, production-series checking devices, and multidimension checkers.

• **Introducing statics**—Static control is just starting to make its way into the Italian machine tool industry. Pioneer in this field is Ercole Marelli & Co. S.p.A., which has a technical agreement with Westinghouse and has started producing (under license from the American firm) Package-Drive, Mototrol, Rectiflow, and Load-O-Matic static control equipment.

Experimenting with static control are three of Italy's biggest machine tools manufacturers: Maxnovo on a grinder, S. Eustachio of Brescia on a plano-milling machine, and Minganti of Bologna on a boring mill.

—Gene Di Raimondo
McGraw-Hill World News

AROUND THE BUSINESS LOOP

STL—How Independent?

A look into the record clarifies the status of this Ramo-Wooldridge offspring following the establishment of the new Thompson Ramo Wooldridge Inc.

Los Angeles—

On Nov. 1 of last year, The Ramo-Wooldridge Corp. and Thompson Products, Inc., formally announced that their merger had been concluded and that the name of the newly consolidated company would be Thompson Ramo Wooldridge Inc. (no hyphens, no commas).

There was an unusual feature to this important but routine report. One of the divisions of R-W, namely Space Technology Laboratories, had come out of the merger talks a separate corporation, having no operational connection to either R-W or Thompson. CtE noted the approach of this status for STL in October (page 52), when it reported the selection of James H. Doolittle as chairman of the STL board of directors. But it did not mention that the assets and liabilities of the new corporation would balance out at a healthy $8,340,000. Here is what happened.

• **First came Thompson**—When Ramo-Wooldridge, which subsequently organized Space Technology Laboratories, was itself formed in 1953, it was backed by Thompson Products. Financing was through $350,000 in preferred stock and $49,000 in common stock, sold to Thompson, and $51,000 in common stock sold to R-W executives. Two years later, Thompson gave R-W an expansion assist of $20 million and received an option to buy up to 85 percent of R-W common stock by 1965.

The Thompson-Ramo merger, first reported in CtE in August 1958 (page 19), was, therefore, more or less preordained. So, for the same reasons, was Thompson control of STL, though this did not come until STL's parent Ramo-Wooldridge had received approval from the government to purchase stock from STL and thus transform this division into a full-fledged corporation.

• **Then Ramo-Wooldridge**—At its inception as a corporation, STL issued and sold to R-W 53,000 shares of cumulative preferred stock, valued at $100 a share, and 1 million shares of common stock, at $1 a share. Total value: $6,300,000. This stock was transferred to R-W "in exchange for the assets of Ramo-Wooldridge appropriate for the business of Space Technology Laboratories", to quote from the files of the Div. of Corporations of the State of California. The fair value of these assets was put at more than the $6,300,000.

The new corporation, Thompson Ramo Wooldridge Inc., succeeds to the ownership of all of STL's preferred stock and to 88 percent of its common stock. The remaining 120,000 shares of common (12 percent of 1 million) will be used for granting stock options to STL officials.

• **Then both**—The upshot is clear: Thompson Ramo Wooldridge has taken all the necessary steps to protect its investment in STL. And a wise thing, too, in view of the fact that STL's net profit for 1958 is expected to run close to $3 million—the bulk will be from its technical management of the Air Force's ballistic missile program. All major STL financial transactions will require the approval of TRW. Say STL's incorporation by-laws in this respect:

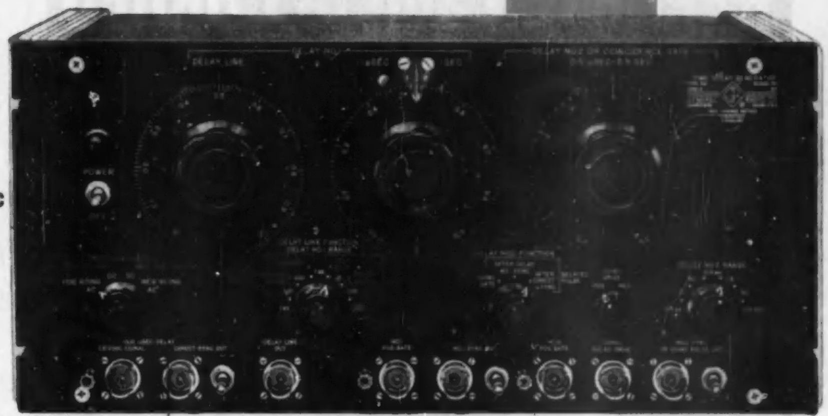
"As long as Thompson Ramo Wooldridge Inc. shall be beneficial owner of 50 percent of the common stock of the corporation, Space Technology Laboratories, Inc., cannot create any funded debt without the written consent of the Board of Directors of TRW."

It is also true, however, that no control but financial control is being exercised by TRW over the new corporation. There are no TRW people on the STL board of directors: STL executives are officially as well as physically separated from the TRW organization—the Ramo-Wooldridge segment of TRW is relocating as a separate TRW division 30 miles from the STL facilities*. In a word, the STL management has a free rein technologically.

• **$22 million in '57**—A statement of operations for Space Technology Laboratories, for the first six months of 1958, reveals gross sales to June 30 of $18,182,839. In the entire year before this six-month period, gross

* Also given divisional status by TRW is the Thompson-Ramo-Wooldridge Products Co., which specializes in industrial control and data reduction systems incorporating the RW-300 digital computer.

NEW Type 1392-A TIME-DELAY GENERATOR, $985



- Continuous delay range from 0 to 1.6 sec
- Two independent delay circuits; 0 to 1.1 sec and 0.5 μsec to 0.5 sec
- Ten-turn dial calibration is exact everywhere even on 1-10 μsec range
- Built-in provision for time modulation
- All long delays have associated gate pulse outputs
- Coincidence circuitry for producing exact delays or bursts, and for calibration
- Input circuits accept almost any waveform from dc to 300+ kc to initiate action
- High accuracy, high linearity, high resolution, low jitter

INPUT SYSTEM

- **Input Voltage Required:**
  Sine Wave: 0.1v rms
  Square Wave: 0.3v, p-p
  Pulse (+ or −): 1-volt peak
  Input trigger threshold control provided
- **Frequency:** dc to 300+ kc
- **Delay** from Input Terminal to Direct Sync Terminal: 0.12 ± 0.02 μsec
- **Direct Sync Pulse:**
  Amplitude: ± 15v
  Duration: 0.13 ± .02 μsec
  Impedance: 93Ω

DELAY CIRCUITS

	DELAY NO. 1	DELAY NO. 2
Range	0-1.1 sec in seven ranges	0.5 μsec-0.5 sec in six ranges
Accuracy	0-1 μsec range: ±0.01 μsec. Remainder of range: ±1% of dial reading	±3% of dial reading
Jitter	1:30,000 at worst	1:20,000
Line Drift	1:10,000 with 20% line change	1:5000 with 20% line change
Resolution	0-1 μsec range: 0.004 μsec. Remainder of range 1:8800	1:2000
Output Sync Pulse		
Duration	0.1 ± 0.02 μsec	0.13 μsec ± 0.02 μsec
Amplitude	± 25v	± 20v
Output Impedance	93Ω	93Ω
Max. PRF	for 0-1 μsec, 300 kc; 1 μsec to 1.1 sec, 250 kc	300 kc
Duty-Ratio Effects	For duty ratios up to 60%, dial accuracy is 1% as specified; accuracy is 5% at 80% duty ratios	Less than dial accuracy at full scale for duty ratios up to 60% and at bottom end of scale for duty ratios up to 20%

COINCIDENCE CIRCUIT

Input: positive or negative pulse, 5v or over
Input Frequency: 1 cps to 1.7 Mc (for single pulse selection)
Input Rise Time: 0.1 μsec or less at 5v

The most precise and flexible delay generator available, the 1392-A uses linear sawtooth waveforms and accurate amplitude comparators to produce two variable delays. Gating-on errors encountered in digital equipment are eliminated, yet the accuracy of delay is comparable with digital apparatus when the 1392-A is used with a source of quartz-crystal controlled pulses.

An external signal source establishes within the Time-Delay Generator a 0.1 μsec synchronizing pulse which serves as the time reference. Two independent variable delay circuits provide delays relative to this reference sync pulse from 0 to 1.1 seconds (Delay No. 1), and from 0.5 μsec to 0.5 seconds (Delay No. 2). These two delay circuits can be operated "in series," (adding in delay times) or "in parallel," producing two independent delays.

The DELAY NO. 1 circuit includes a passive variable delay line with a precisely calibrated dial to produce incremental delays from 0 to 1 μsec in 10-mμsec divisions. This delay line can be used either as the first range (0-1 μsec) for Delay No. 1, or as a verniér on the 1-μsec to 1.1-second electronically produced delay. It can also be used to delay the sync pulse produced by Delay No. 2, or to delay an input signal.

DELAY NO. 2 is in principle similar to Delay No. 1, but its associated gate can be used to actuate a coincidence amplifier. In coincidence operation, the gate is opened by the Delay No. 1 sync, and its duration is set by the Delay No. 2 circuits. Delay No. 2 times the gate, and does not produce a sync output. In this way, pulses from a timing comb which are present while the gate is open can be selected. For example, the 0.5-μsec minimum setting of Delay No. 2 permits the selection of a single 1-μsec pulse from a 1-Mc train to provide 1-μsec steps of delay. In addition, the coincidence feature can be used to produce bursts of pulses from a timing comb.

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sales totaled just slightly more, or \$22,248,494.

Taking the helm of STL at this important turn in its history is Louis G. Dunn, formerly executive vice-president and general manager, and before that director of Cal Tech's Jet Propulsion Laboratory. Ruben F. Nettler succeeds him.

—Michael Murphy
McGraw-Hill News

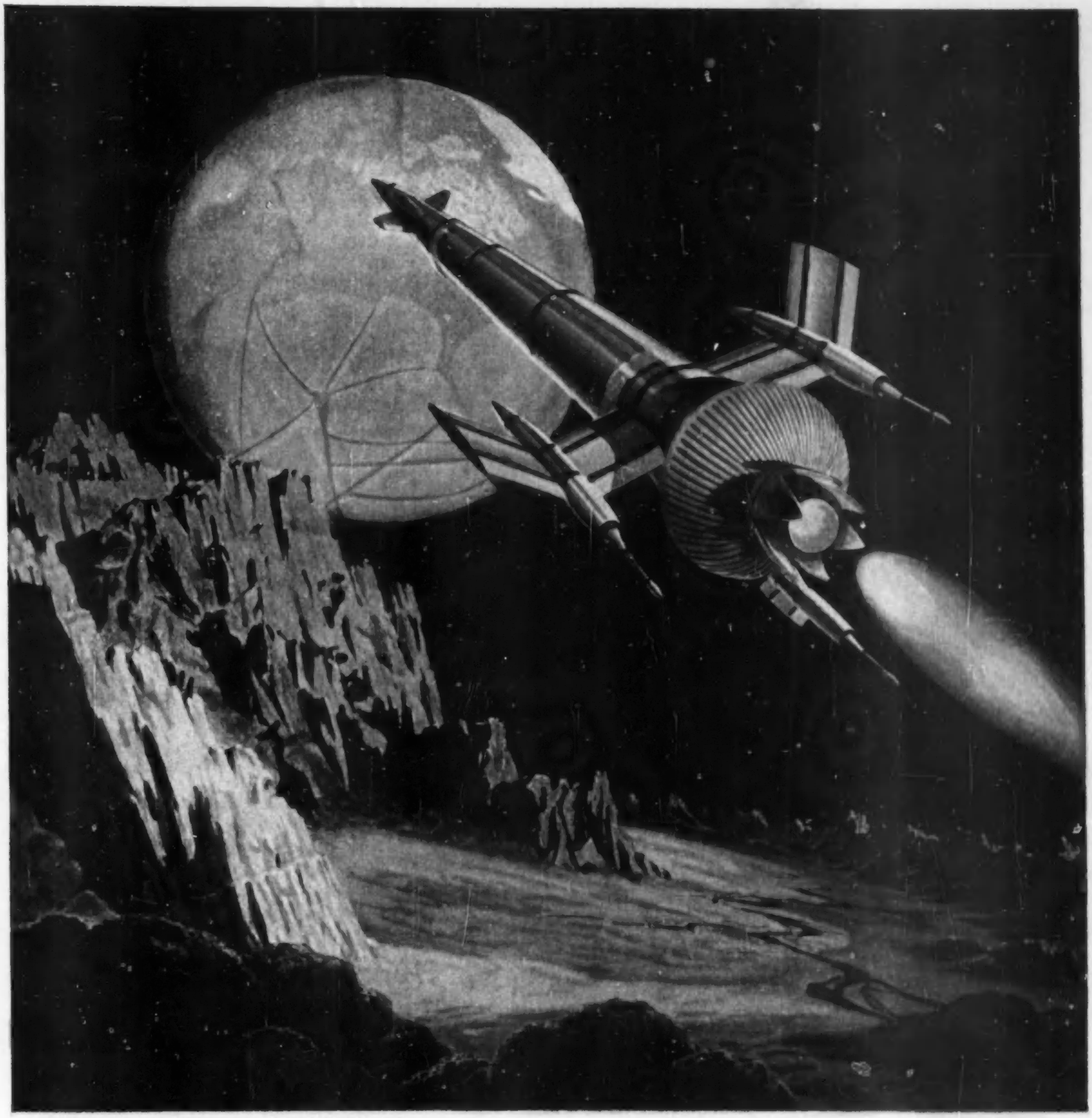
Midwestern Upheld; CEC's Suit Fails

In the Tenth Circuit Court of Appeals in Denver, Colo., recently, Midwestern Instruments, Inc., successfully defended itself for the second time against an unusual charge of contributory infringement, brought by Consolidated Electrodynamics Corp. It signaled the end of about six years of legal hassling between the two companies, in the course of which the suit against Midwestern was filed in 1956.

The decision in Denver affirmed an earlier one, in the U. S. District Court for the Northeastern District of Oklahoma. Here, in January 1956, CEC complained that Midwestern was infringing on a CEC patent protecting a "winged" galvanometer. More specifically, the charge was that Midwestern's royalty payments did not recognize all of CEC's rights to the galvanometer: Midwestern was paying royalties on the receiver (a slotted alignment and adjustment device), said CEC, but not on the galvanometer itself.

In the trial Midwestern disclosed that even while it had been paying its royalties to CEC on all galvanometers with the special receiver design, it had been quite convinced that this design was in the public domain. It had had its eye, Midwestern explained, on expediency and the high cost of litigation. But when it brought out a new receiver, once more incorporating the CEC design but able to be separated from the galvanometer, CEC returned its payments and filed the suit. The reason given was that Midwestern was now basing its payments only on the receiver, and this was contributory infringement.

In its defense, Midwestern established its own claim to the galvanometer proper, then the invalidity of the CEC patent on the receiver. As a result, the court ruled that it was unnecessary to consider the question of contributory infringement.



STEPS IN THE RACE TO OUTER SPACE

Mars Snooper

This nuclear-fueled reconnaissance craft is preparing to land on Mars' outermost satellite, Deimos—12,500 miles away from the "red planet" (center) and 35 million miles away from the Earth. Deimos' gravitational pull is so slight that a featherlight landing could be made, and a take-off could be accomplished with little more than a shove of the pilot's foot! (At Deimos' orbital speed, such a push would start the ship back to Earth at 3000 miles per hour.)

Our spaceship is designed to fly in two directions—nose first as a space rocket and tail-first as a ramjet airplane. Propulsion for both is provided by a single atomic heat source, reacting with hydrogen for rocket thrust, and with atmosphere to power the ramjets.

Travel to Mars, braking for landing, take-off and re-entry are accomplished by rocket-thrust. As the ship approaches the Earth's atmosphere, it assumes a tail-first attitude. The "petal doors" enclose the rocket nozzle, and the ship is transformed into a high speed, ramjet airplane with M-shaped wings. Control fins are located in the nose of the craft, near the crew's quarters.

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ARMA needs key men to augment a broad research program in missile guidance and space technology. As designer and developer of all-inertial navigation systems for TITAN and ATLAS ICBM's, ARMA provides a stimulating atmosphere where creative talents can develop. Write to E. C. Lester, Professional Placement, CE-2, ARMA Division, Garden City, N. Y. A Division of American Bosch Arma Corporation.

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CIRCLE 40 ON READER-SERVICE CARD

A Control Community

Opening of Barden Corp.'s new plant in Danbury, Conn., prompts a look at this town as a center of advanced engineering.

Though never poor industrially, Danbury, Conn. (population 42,900), for some time had been a town without a central industry. After the Revolutionary War—Danbury was about 100 years old then—the hatting trade came, prospered, and stayed. But by the end of World War I, its effectiveness as a backbone business was weakening, and men who could read the signs formed the Danbury Industrial Corp. to attract and nourish new firms. It was then that its first control-oriented firm came to Danbury.

The company was Danbury Electric Mfg. Co., which was to change its name in 1930 to Danbury-Knudson. It took its place with such growing enterprises as Doran Brothers, Inc., and The Boesch Mfg. Co., Inc., which were already reflecting Danbury's success in diversifying its industry. And in 1942, The Barden Corp., then a subsidiary of Carl L. Norden, Inc., settled in town.

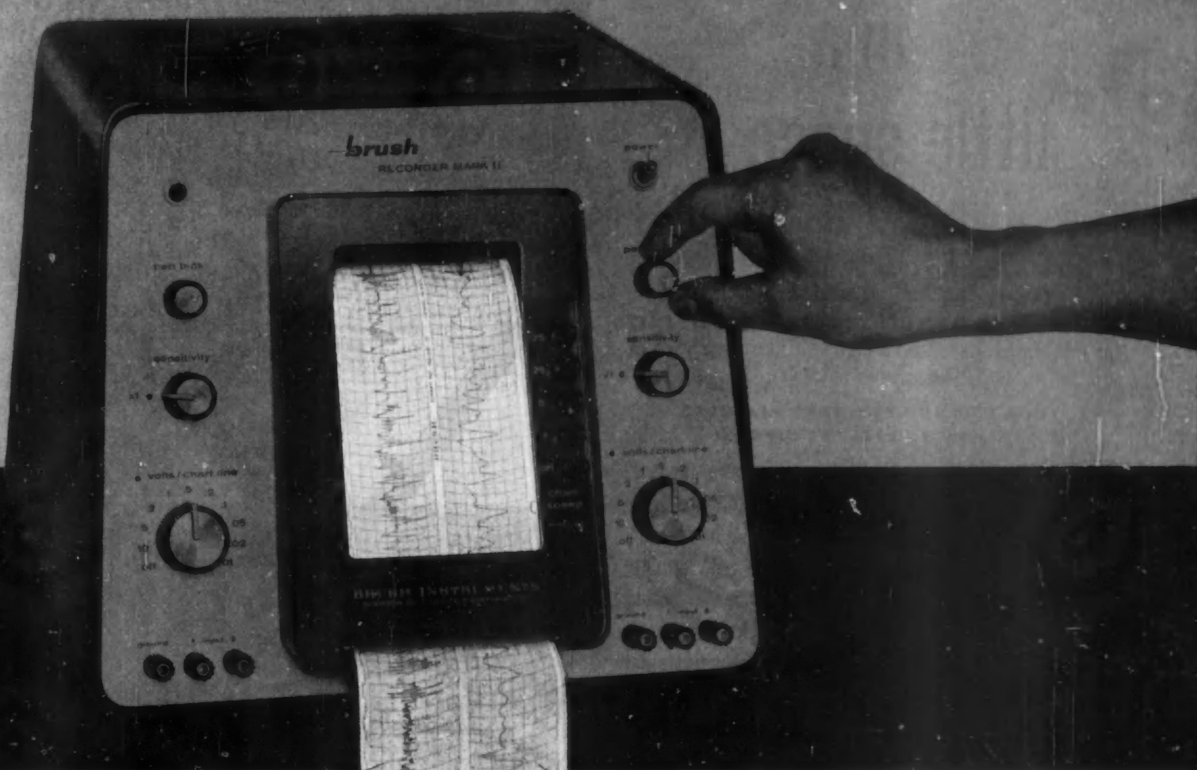
• **Now there are eight**—At least eight major control firms have their home office, a division, or an important branch office, in Danbury today, making the town, without a doubt, a control engineering community—and giving it, once again, a central industry. Of the eight firms—of any firm in Danbury, in fact—Barden, with a payroll of 1,000, is the biggest employer. Not since hatting's greatest heyday, when the largest hat shop employed 1,500, has one company in the town fed so many families.

Last November, Barden opened a brand new \$2.5 million plant (125,000 sq ft) on Danbury's Park Avenue—Route 7. In value and size, the plant is far removed from the Tweedy Silk Mills, once a Danbury hat bindery, which was Barden's first home. So naturally, the opening was significant. But it was significant on another count as well: it was a dramatic reminder of Barden's successful separation from the old Norden company.

Since the end of World War II and the end, therefore, of the Norden bombsight, one of Barden's greatest challenges had been to sell the ability of its engineers to handle new and tough ball-bearing problems, and to do this on its own, without the help of the Norden name. Barden's last

(Continued on page 150)

The New Brush Mark II opens up whole new world of direct writing applications



Sensitivity
10mv/line (mm). Full scale deflection from chart center ± 200 mv.

Measurement Range
.010v. to 400v.

Input Impedance
5 megohm single-ended, 10 megohm balanced.

Frequency Response
D.C. to 100 cps.

Recording Channels
Four, 2 event channels and 2 analog.

Chart Speeds
1, 5, 25, 125 mm/sec.

Power Requirements
105-125v., 60 cps, 135 watts at 115v.

The portability and remarkable simplicity of the Brush Mark II make it practical to use *anywhere.*

Wherever you work—in research, design and development, production, field testing—you get an immediate *ultralinear* record of performance . . for quick analysis and corrective action on the spot . . . for study at a later date . . . . for reproduction by conventional low-cost copy methods.

As foolproof as you'd hoped for, this recorder has built-in amplifiers, permanent calibration, instant paper loading and a "white glove" writing system. Use it as a recording voltmeter . . . as a supplement to your "scopes".

CALL-WRITE-WIRE for immediate shipment from stock—$1350 F.O.B. Cleveland.

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DIVISION OF
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a LOT of Relay in a little space

New Class "E" Relay measures only $2\frac{1}{4}$" x $1\frac{1}{8}$" x $1\frac{13}{64}$" minimum (2 springs) to $1\frac{23}{32}$" (10 springs)

This latest Automatic Electric achievement compacts all the features of the famous Class "B" relay in minimum space and weight—with no sacrifice of quality or ruggedness.

LOOK AT THE IMPORTANT FEATURES THIS NEW CLASS "E" OFFERS:

• miniaturized; telephone-style base mounting for rear-connected wiring • heavy-thickness armature arms prevent loss of stroke with large pileups • heavy-duty backstop that won't break or wear out • adequate terminal clearances for easy wiring • long-life, lubricant-retaining bearing arranged to provide a visual check of the heel-piece airline setting without disturbing the adjustment • twin contacts standard; all springs bifurcated for maximum independence • sturdy, strain-relieved heelpiece insures stability of adjustment

Class "E" Relays are available in the following series:

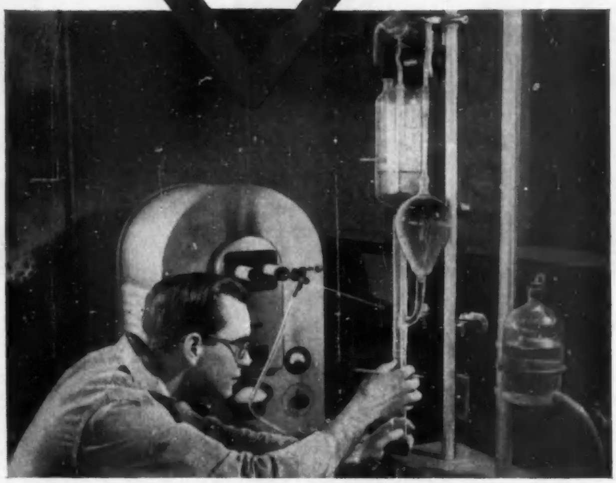
EQA—Quick Acting	ESA—Slow Acting*
ESO—Slow Operate	EFA—Alternating Current
ESR—Slow Release	EMS—Snap Action Contacts

*slow operate and slow release

Class "E" Relays can be supplied plug-mounted (with or without cover) or hermetically sealed (maximum 4 springs per pileup) in enclosure AE-3300.

• • •

For more information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*



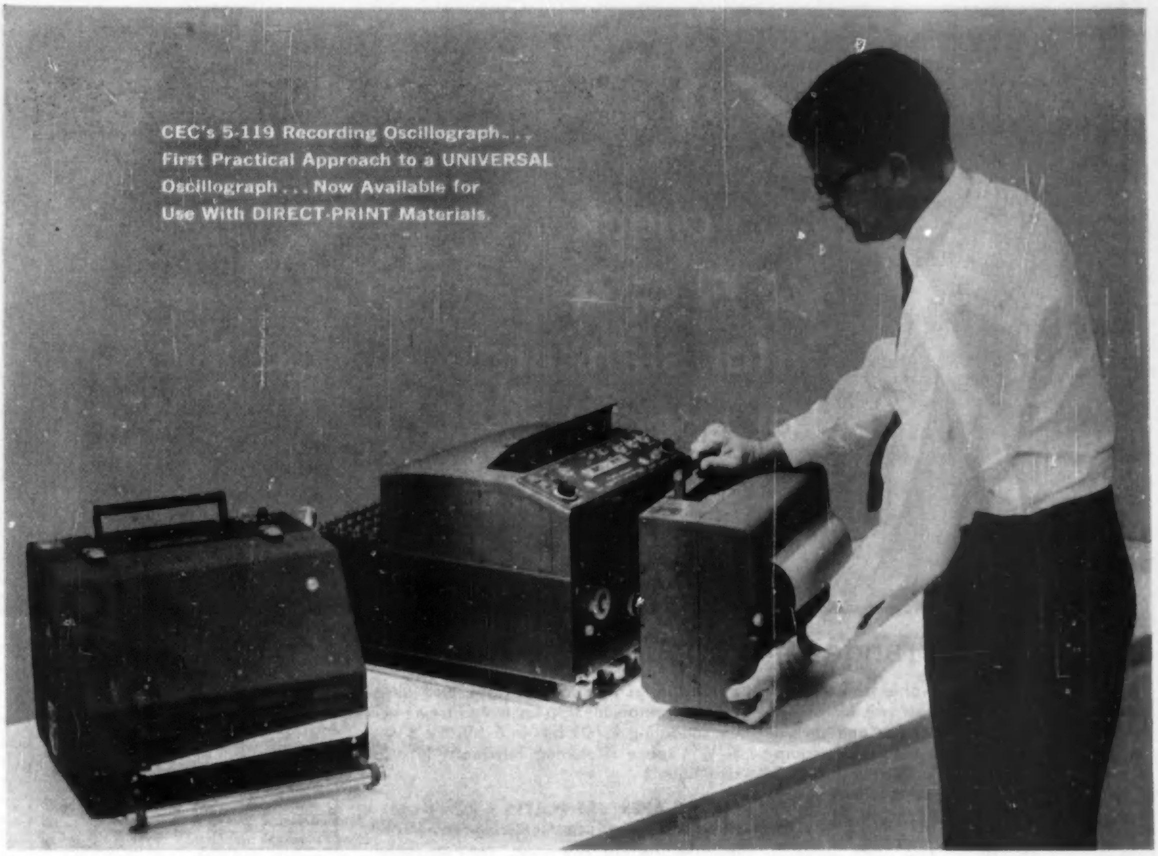
99% pure isn't pure enough—the relay iron we use at Automatic Electric must meet specifications of 99.8% purity, including, for example, carbon content limit of .02. To obtain highest magnetic permeability, material is treated for periods up to 7 hours in roller hearth annealing furnaces. Highest standards of quality control insure the well-known dependability of AE Relays and Switches.

AUTOMATIC ELECTRIC

Northlake, Illinois

Subsidiary of **GENERAL TELEPHONE**

 CIRCLE 43 ON READER-SERVICE CARD



New recording versatility with 3 interchangeable magazines

With a new high-actinic light source and Slot-Exit Magazine, the 5-119 now becomes one of the most truly universal tools of data processing available. Addition of the direct-print process and new magazine to the 5-119 now brings you three uniquely different recording processes, enabling engineers to select the process best suited to specific test requirements.

PROCESS 1 DIRECT-PRINT... Clearly resolves writing speeds to 100,000 ips. High-actinic light source 5-119 P4-36V (or -50V) and new 5-051 Slot-Exit Magazine produce records on standard direct-print papers without chemical processing of any kind. Records emerge from the magazine slot continuously, and latensification takes place in ordinary room fluorescent light.

PROCESS 2 RAPID-ACCESS... Provides the shortest access time of any known process, and yields records of higher trace contrast and greater permanency than afforded by direct-print materials. Process employs the 5-036B DATARITE Magazine which automatically develops and dries oscillogram as quickly as data are recorded. Provides ready-to-read test results almost simultaneously with the occurrence of events under study.

PROCESS 3 CONVENTIONAL... Used where the finest available recording trace and contrast with highest writing speed are paramount requirements. Records are contained by the 5-006A Standard Magazine which uses conventional 12-inch films or papers. Records are processed following the record run.

The 5-119 provides 36 or 50 independent data input channels... Wide record-speed and frequency-ranges... Flash-Timing System to synchronize timing lines of 2 to 100 remote oscillographs. For complete details call your nearest CEC sales and service office, or write for Bulletin CEC 1536-X1.

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS *300 No. Sierra Madre Villa, Pasadena, Calif.*

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

CIRCLE 44 ON READER-SERVICE CARD

check
RCA
for standard
or special
ferrite cores!

...for a wide range of computer applications!

Now—commercially available from RCA—a comprehensive line of fast-switching, low- and high-drive, memory cores and several new memory-plane designs to provide equipment designers with one of the broadest lines of memory core products in the industry.

MEMORY CORES • In addition to a line of standard ferrite cores developed for coincident-current memory applications (ranging in switching time from 0.2 μ sec. to 3 μ sec.), RCA now offers a new group of ferrite cores particularly suited for both high-speed, word-address memories, and slow-speed, low-drive coincident-current memories. These cores are available for an applied field (H_0) ranging from 0.2 to 1 oersted, and in sizes from 0.050" x 0.030" to 0.370" x 0.290". The smaller-size cores make possible the design of high-speed memory devices with driving currents suitable for either transistor or tube drivers. Typical characteristics are given in the table.

MEMORY FRAMES • A compact, rugged aluminum frame utilizing a new stack-wiring concept makes possible a "bit-packing factor" greater than ever before. 8,192 bits may be stored in a 7" x 7" x 0.3" frame. For more economical designs and even greater compactness, a laminated frame accommodating 8,192 bits in a 5½" x 5½" x ¼" space (including terminals) is also available.

FERRITE APERTURE PLATES • RCA's apertured-plate construction utilizing ferrite-core material having low-drive, medium-speed characteristics, can store 256 bits of information in a space less than 0.9" x 0.9" x 0.025", thus making possible the design of compact memories for transportable equipment in which minimum weight and space are vital considerations.

The aperture memory plates have a nominal full driving current requirement of 320 ma., a switching time of about 1.8 μ sec., and an undisturbed output (1) signal (uV_1) of greater than 40 mv. making them especially suitable for use in transistorized circuits. In addition, the precision registration of the holes makes it possible to stack the aperture plates quickly and accurately.

Rigid production controls insure excellent uniformity of undisturbed output signal and peaking time... testing assures dependable performance of each storage element.

For ferrite cores having uniformity to meet your most exacting design requirements, and for dependable delivery schedules, contact your local RCA Sales Representative.

Typical Characteristics of Ferrite Cores for 2:1 Coincident-Current Applications

RCA Type▲	T_s μ sec.	T_p μ sec.	uV_1 mv.	dV_z mv.	Driving Current ma. (I_m/I_{pw})	T_r μ sec.
XF-3806	.27	.13	160	26	1100/660	.12
XF-4019	.67	.32	106	14	725/450	.12
XF-3018H	1.18	.53	55	9	460/275	.20
XF-4028	1.08	.80	72	4	380/190	.50
XF-3973	1.28	.71	48	5	350/215	.40
XF-3673	2.80	1.35	22	4	210/126	.50
XF-4003	2.60	1.45	24	3	190/95	.50
XF-4004	2.36	1.26	26	5	190/95	.50
XF-4005	4.10	2.35	10	5	125/63	.50
XF-4006	9.0	4.8	4.5	4.5	90/45	.50
XF-4007	7.5	4.3	4.5	5.0	70/35	.50
XF-4008	13.0	6.5	2.0	3.5	40/20	.50

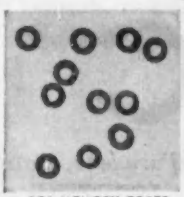
Time is measured from 10% of current rise to 10% of voltage (uV_1) fall.
▲All type numbers are for .050" x .030" x .015" size.

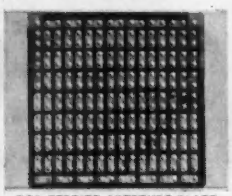
Typical Characteristics of Ferrite Cores for Switching Applications
Switching Time (T_s) μ sec. vs. Applied Field (H_0) in oersteds

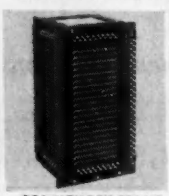
RCA Type▲	Switching Time (T_s)—μ sec. H_0=.8	H_0=1.0	H_0=1.5	H_0=2.0	H_0=3	H_0=4	H_0=5
XF-3806						.22	.18
XF-4019					.41	.24	.163
XF-3018H			1.12	.75	.36	.226	.161
XF-3973			.73	.42	22	.138	.105
XF-3673		1.16	.63	.40	.22	.15	
XF-4003		1.04	.60	.39			
XF-4004	3.84	.90	.52	.34	.194	.129	
XF-4005	3.60	.81	.48	.312	.174		
XF-4006	2.36	.71	.41	.260	.142		
XF-4007	1.38	.48	.28	.194			
XF-4008	1.53	.41	.242	.165			

Time is measured from 10% rise to 10% fall of uV_1. Rise time of current pulse is approximately 35 millimicro-seconds. To convert drive in oersteds to current in amperes: For core size of .050 OD x .030 ID, multiply H x 0.25. For core size of .080 OD x .050 ID, multiply H x 0.41.
▲All type numbers are for .050" x .030" x .015" size.

RADIO CORPORATION OF AMERICA
Semiconductor and Materials Division
Special Ferrites   Somerville, New Jersey


RCA MEMORY CORES


RCA FERRITE APERTURE PLATE


RCA MEMORY FRAME


RCA TRANSFLUXORS

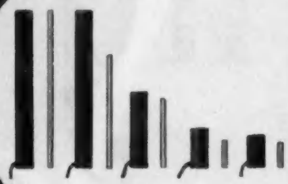
East: 744 Broad St., Newark, N. J. HUmboldt 5-3900
Northeast: 64 "A" Street, Needham Heights 94, Mass. HIllcrest 4-7200
East Central: 714 New Center Bldg., Detroit 2, Mich. TRinity 5-5600
Central: Suite 1154, Merchandise Mart Plaza, Chicago, Ill., WHitehall 4-2900
West: 6355 E. Washington Blvd., Los Angeles, Calif., RAymond 3-8361
Gov't: 224 N. Wilkinson Street, Dayton, Ohio BAldwin 6-2366
1625 "K" Street, N.W., Washington, D.C. DIstrict 7-1260
Route 202, Somerville, N. J. RAndolph 5-4500

SANBORN *Transducers*

FOR LINEAR MEASUREMENTS...

DISPLACEMENT

LINEARSYN Differential Transformers



Six series of Sanborn Linearsyns — three of the shielded type, three unshielded — are available, with five models in each series. Linearity is better than 1% of full scale output in all models. Temperature range is from −50° to 205°F.
Special design features include coil assemblies hermetically sealed in epoxy, laminated phenolic jackets (unshielded types) or heavy plated steel jackets (shielded types), improved lead wire strain relief, high permeability alloy cores. Models with axial leads are also available on special order. Within each series all models have identical diameters, tap sizes, lead wires; only the lengths of coil assemblies and cores vary.

Typical Linearsyn Characteristics

Series* (Unshielded)	Series* (Shielded)	Strokes* (±inches)	Freq. Ranges	Sensitivities* (Volts/inch per volt of excitation at std. carrier freq.)
575DT	585DT	.050 - 1.00	400 cps - 10 kc	.56 - 3.70
576DT	586DT	.050 - 1.00	60 cps - 400 cps	.70 - .90
590DT	595DT	.005 - .100	400 cps - 20 kc	1.60 - 2.60

*Maximum and minimum values available within each series; data on individual models on request.

VELOCITY

LVsyn Velocity Transducers

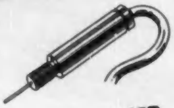
LVsyn pickups may be used to measure *linear velocity* directly, *displacement* with a simple integrating circuit, or *acceleration* with a differentiating circuit. There are twenty-four models, all self-generating with shielded cylindrical coil assemblies and high coercive force permanent magnets. Twelve models use regular magnet cores; twelve have *non-breakable* magnet cores. Characteristics of the two groups are the same except for output sensitivity, core length and weight. Features include high sensitivity, single-ended or push-pull output, accurate and stable calibration, unlimited resolution, wide range of sensitivities and sizes, temperature range of −50° to 200°F. They can be immersed in hydraulic fluid. No mechanical connection between coil and core permits low friction level. End stops or displacement limits not needed; undamaged if limits are extended.

Typical LVsyn Characteristics

Model	Displacement: Nominal Working Range (Inches)	Displacement: Maximum Usable Stroke (Inches)	Electrical Characteristics: Voltage Output mv/inch	Total Impedance Series Connection R ohms	Total Impedance Series Connection L henrys
3LVA5*	0.50	1.30	120	2,000	0.085
6LV2*	2.0	3.4	500	19,000	2.4
6LV2-N	2.0	3.4	250	19,000	2.4
7LV9*	9.0	11.0	350	17,000	2.8

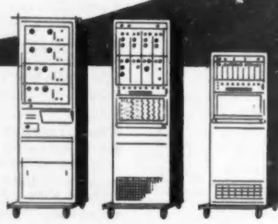
*Four of the twenty-four models available, selected to show minimum, approximate mid-range and maximum working ranges as well as the difference in sensitivity between a regular magnet core model (6LV2) and a non-breakable magnet core model (6LV2-N).

NEW!



COMPLETE DISPLACEMENT TRANSDUCER

"Probe" style, uses differential transformer. With cable and adapter for connection to Sanborn 150, 350 Series Carrier Amplifiers. Stroke ±0.070", high sensitivity, linearity 0.5%, infinite resolution, contact pressure as low as 10 grams. Stainless steel body, carbide tipped contact rod, jeweled bearings. Two models: 580 — plug-in cable, flange mounting; 581 — miniature, integral cable.



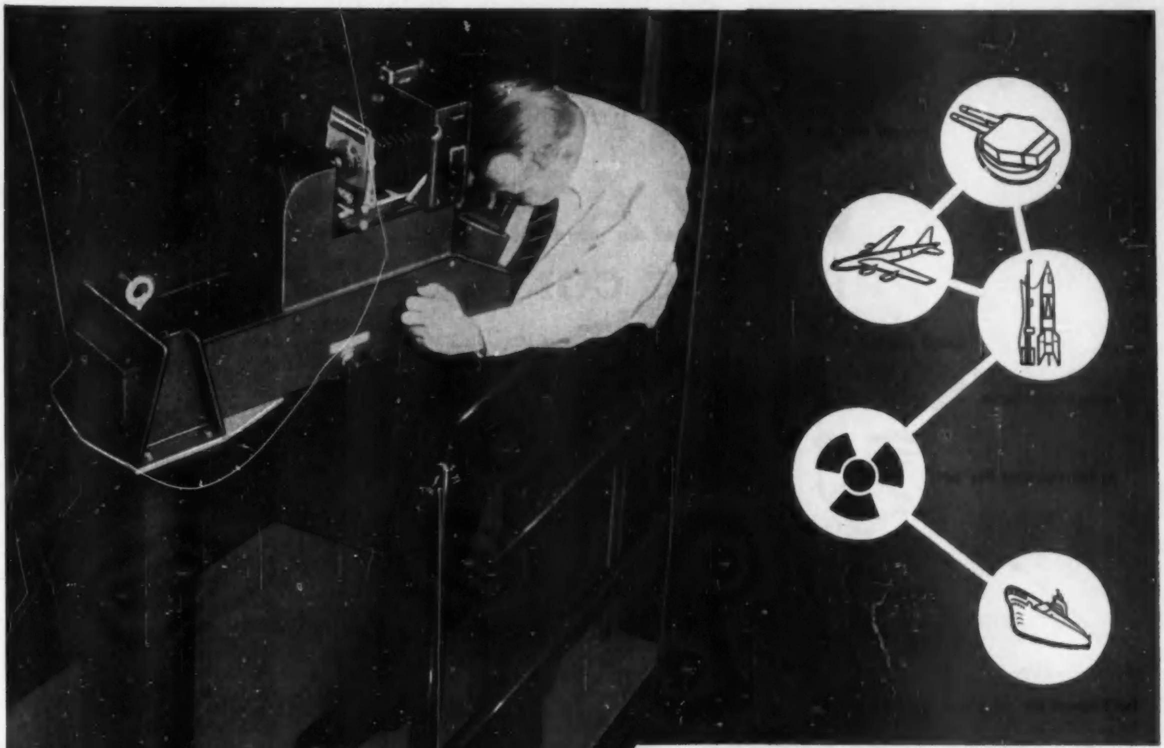
for MULTI-CHANNEL RECORDING

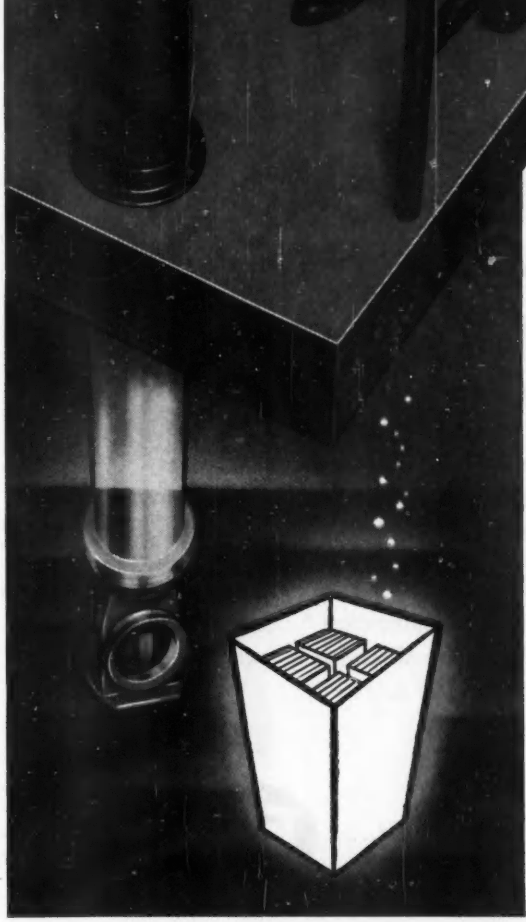
Sanborn direct writing systems now include 1- to 8-channel "150" Series, with a choice of 12 plug-in Preamplifiers; new single-cabinet, compact 6- and 8-channel "350" and "850" Series with interchangeable Preamplifiers, flush-front recorder with electrical pushbutton chart speed control and transistorized Power Amplifiers, and numerous features for high reliability and operating convenience.

For complete facts, call your local Sanborn Industrial Sales-Engineering Representative or write the Industrial Division in Waltham.

(All data subject to change without notice)

SANBORN COMPANY
Industrial Division
175 Wyman Street, Waltham 54, Mass.





If it can't be seen, but must ...call in Kollmorgen

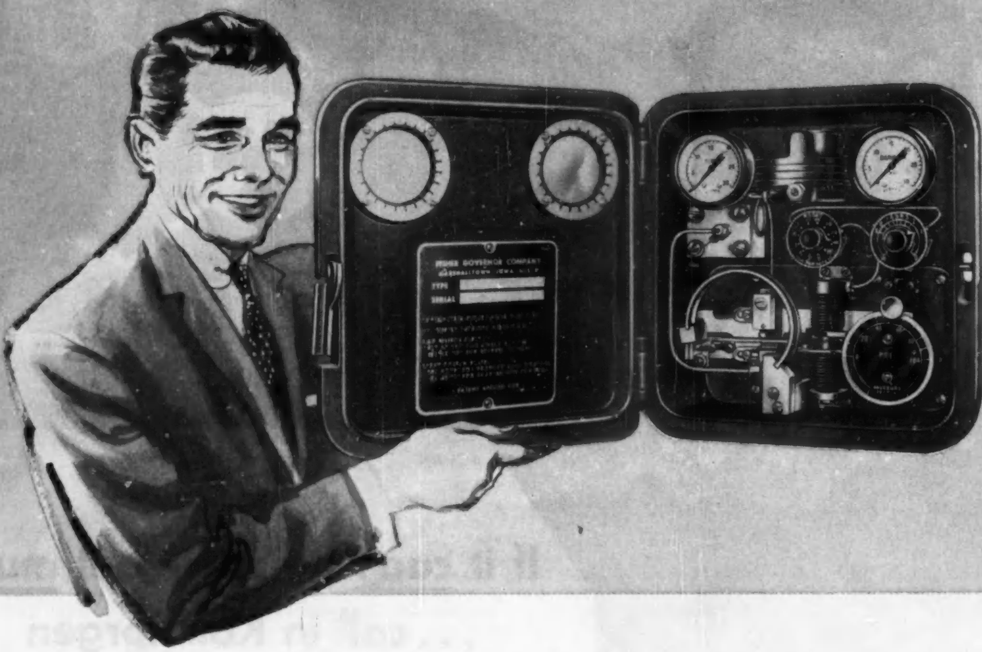
Kollmorgen optical-mechanical viewing systems have been bridging the gap between the eye and the "invisible" for almost fifty years. Kollmorgen instruments range in size from small borescopes to submarine periscopes; range in type from nuclear and missile periscopes through precision camera lenses and alignment telescopes, to a variety of optical testing and measuring devices; range in quantity from one of a kind to production runs of thousands.

So, if you have a gap to bridge, let us know its nature... is it water, heat, darkness, radioactivity or simply inaccessibility? We may well have the answer in our files. If not, we will endeavor to provide one quickly. A rough sketch of your problem will be enough to get us started. Write Dept. 211.

KOC KOLLMORGEN
optical corporation
NORTHAMPTON, MASS.

So many ways the *FISHER/MAN* can give you a helping hand with the

WIZARD II
PRESSURE CONTROLLERS



- Two Position Controller
- Proportional Controller
- Proportional Controller —Remote Set
- Differential Proportional Controller
- Pressure Transmitter
- Differential Proportional Controller— Remote Set
- Proportional Reset Controller
- Differential Proportional Reset

This "Jack of ALL Trades" is surprisingly low in cost

The partial list of applications at left tells you why the Wizard II is so aptly named. Probably no other controller in the Fisher line is as versatile. Available in brass, steel or stainless steel Bourdon tubes for ranges from 25 to 10,000 psi. Brass or stainless steel bellows available for low pressure service from 30" Hg Vacuum to 30 psi.

Fisher has carefully designed each component of the new Wizard to satisfy the most rigid process control requirements. A completely descriptive and illustrated booklet on the Wizard II is yours for the asking. Write for Bulletin D 4150 A.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

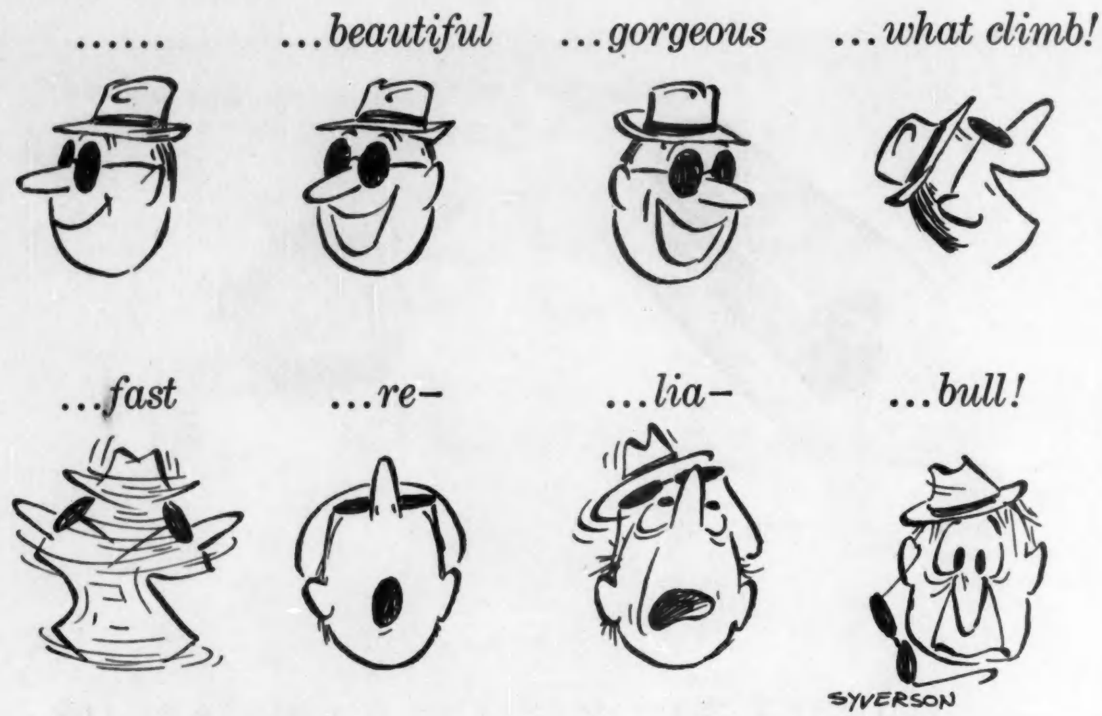
FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

FISHER

SINCE 1880


......
...beautiful
...gorgeous
...what climb!
...fast
...re–
...lia–
...bull!
SYVERSON

Ampex Digital Tape Handlers

Compatible and a speed for each application

In back is the much talked of Ampex FR-300. Its 30,000- to 90,000-character-per-second transfer rates set a lively pace for the fastest digital computers. But these speeds must be brought back to earth for slower peripheral equipment. The Ampex FR-400 on the left is exactly the machine for this job. Tapes are transferable between the two (and also meet widely accepted industry standards).

The FR-400 can be likened to the entry and exit roads feeding traffic to a super-speed freeway. To put data into computer format, it serves in such conversions as analog-to-digital, punched-tape-to-magnetic-tape, and cards-to-tape. On the other end, the FR-400 feeds printers that get the answers back in writing. The FR-400 is also used for input/output for slower computers, but that's another story.

WORKHORSE QUALIFICATIONS

Carrying the freeway analogy a step further, imagine the traffic snarls that occur when exits are blocked. The Ampex FR-400 has a similar responsibility in the digital-data flow. It has been designed with tremendous stamina. It stays on the job.

For example, the FR-400's pinch-roller assembly passed a 15,000,000-cycle start-stop endurance test in our laboratory. Its design is the same as on the higher-speed FR-300. Also, the FR-400's torque motors are like those on the faster FR-300. And the heads are typical Ampex quality, made to take thousands of hours of wear without serious change.

A heavy-duty machine needn't demand heavy-duty people. The FR-400 has quick, easy in-line tape threading. Local controls are an available option, very convenient for tape change and equipment checkout. Then remote controls can take over – even from a source wired in from 1000 miles away.

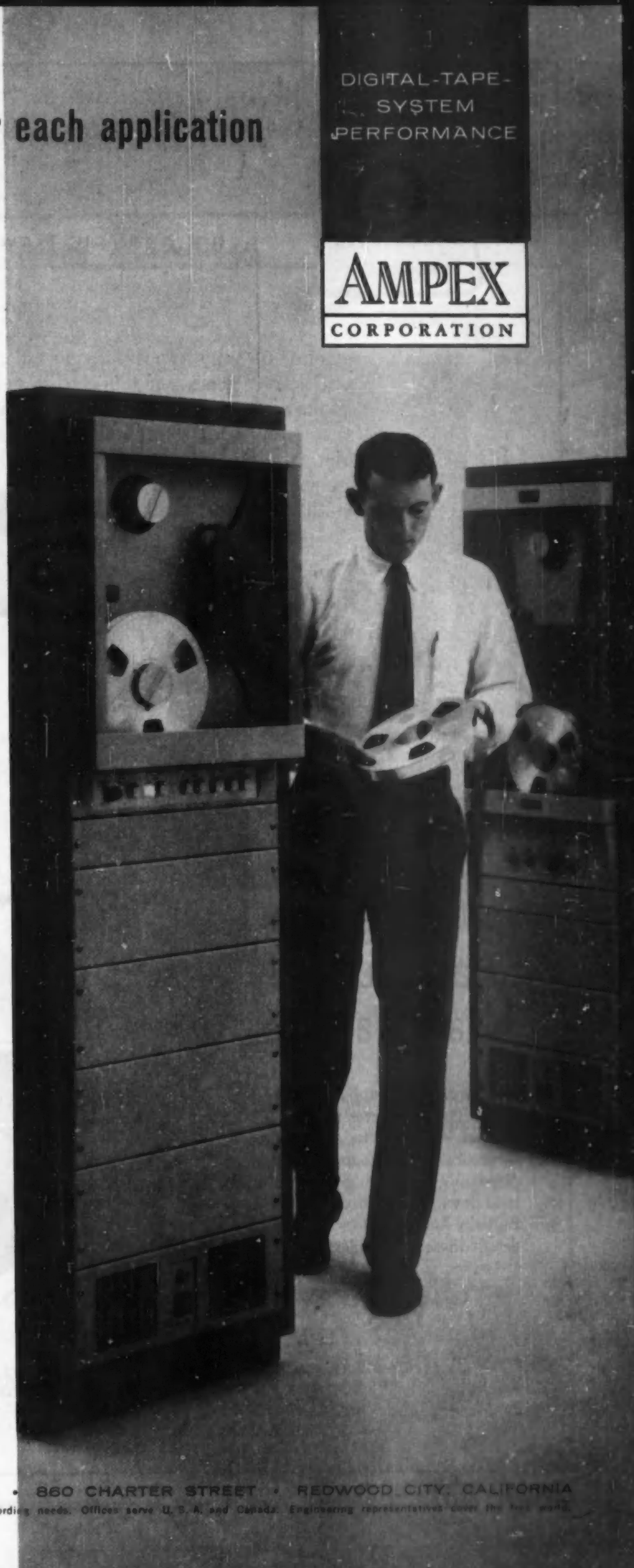
COMPATIBILITY OF SPEEDS

In the matter of speeds, the FR-400 is like a power-line transformer that steps voltages down to the required levels of electrical equipment. Typical tapes made off computer by Ampex FR-300s involve transfer rate of 30,000 bits per second. Tape speed is 150 in/sec. Suppose a particular printer operates at 6000 characters per second. An FR-400 with 30 in/sec tape speed cuts transfer rate to ⅕th making the tape compatible with the printer's speed.

This can be carried still further – for example, to 5 in/sec tape speed and a 1000 character-per-second transfer. For still slower devices like paper-tape punches or card punches, a storage buffer is used. The magnetic-tape handler operates on a start-stop basis. A short burp fills the buffer. The card or paper-tape punch trails along after.

The FR-400 is available in a wide range of basic speed pairs. But Ampex also provides for sharing of tape handlers among conversion and readout devices of widely differing transfer rates. For this the FR-400 is available in 4-speed multirange versions, having two independent capstan motors. Thus the pairs of speeds may be very widely separated. 75, 37½, 10 and 5 inches per second is a typical example.

May we send specifications and descriptions on Ampex's various digital tape handlers or assist in some specific application? Write Department HH-1



AMPEX INSTRUMENTATION DIVISION • 860 CHARTER STREET • REDWOOD CITY, CALIFORNIA

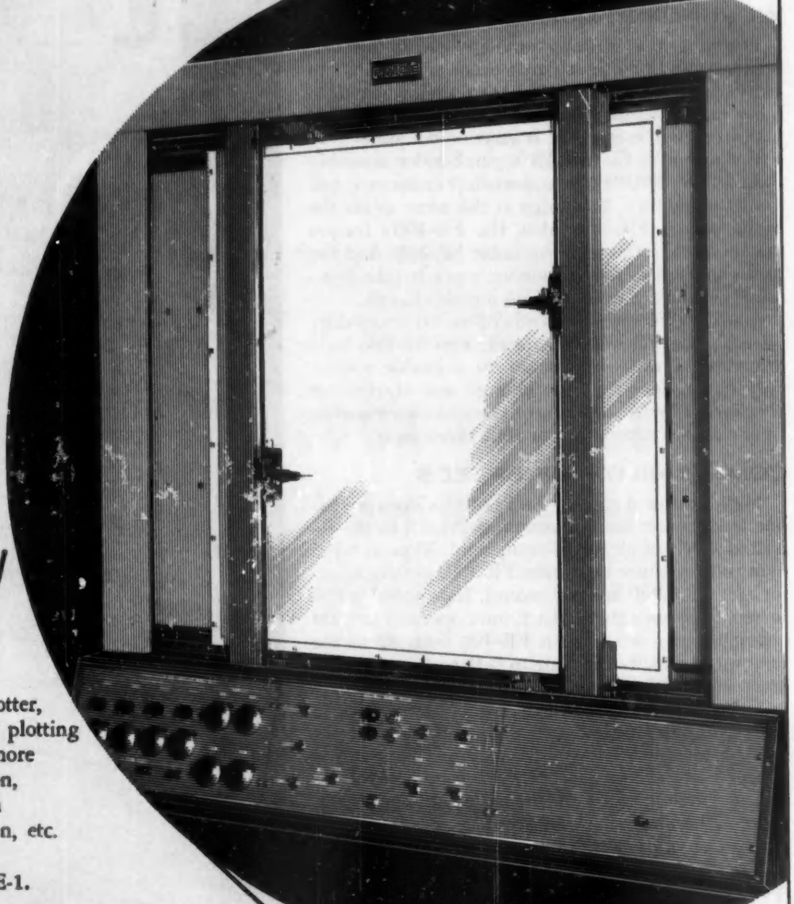
Phone your Ampex data specialist for personal attention to your recording needs. Offices serve U. S. A. and Canada. Engineering representatives cover the free world.

CIRCLE 51 ON READER-SERVICE CARD

ELECTRONIC ASSOCIATES *Incorporated*

LONG BRANCH, NEW JERSEY · CAPITOL 9-1100

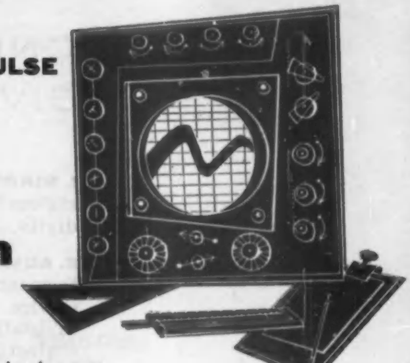
- Smaller Size
- Less Weight
- Faster Response
- Greater Reliability
- Instant Warm-up



EAI's new Transistorized Variplotter, Model 205-T, assures these X-Y plotting advantages and includes many more — vertical or horizontal operation, disposable ink cartridges, vacuum hold-down, established reputation, etc. Bulletin No. PIR 841 further details these advantages. Dept. CE-1.

EAI's new Transistorized Variplotter,

Have you explored the advantages of analog simulation in solving your design problems? Write for Application Bulletins describing successful applications in your industry.



1959: Calm After the Storm

To the control field, which has become accustomed to tremendous annual growth—a tripling in product use every ten years—**1958 was a major disappointment.** As year-end figures were added up, most companies were ready to accept sales totals that were below those of 1957; many had to accept less. Control users, caught in the same economic squeeze, had to settle for less ambitious application programs and had to get down to the fundamentals of economic justification.

There seemed to be no sharp, definite trend. A few companies were still able to report banner years. Texas Instruments, for example, continued its phenomenal growth through the economic storm; its nine months' statement reported sales of $64 million, up 33 percent over last year. But for the average company, 1958 sales dipped 5 to 10 percent and net income fell even further.

Improvement ahead

1959 offers prospects for improvement. Probably the two major factors affecting control usage are military expenditures—particularly those for developments in space, missiles, and aircraft—and capital expenditures for production plant and equipment. For 1959, one is up considerably, the other is down slightly.

Military spending is on the rise. The missile program will be in high gear throughout 1959 and this will mean much activity throughout that part of the control industry which supplies missile and aircraft builders. There will be continued heavy demand for a variety of test instrumentation and system components. Military spending plans for 1959 (in millions of dollars):

	Fiscal 1958	Fiscal 1959	1958-59 Percent Change	Fiscal 1960 (est.)
Missile production	$2,700	$3,400	+26%	over $4,000
Aircraft production	8,400	7,200	−14	under 6,500
Missile R&D	432	500	+16	at least 600
Aircraft R&D	272	245	−10	about 200
Defense Dept's. Advanced Research Projects Agency[1]	....	200	...	at least 300
Space projects of National Aeronautics & Space Agency	....	225[2]	....	about 400

[1] Bulk of these funds will go for space projects
[2] Includes $117 million transferred from ARPA

Capital spending lower

Not so cheerful, however, are the prospects for capital expenditures, to which activity in process instrumentation and control as well as in machinery control is closely related. According to

ONLY KIN TEL DIGITAL VOLTMETERS GIVE YOU ALL THESE ADVANTAGES

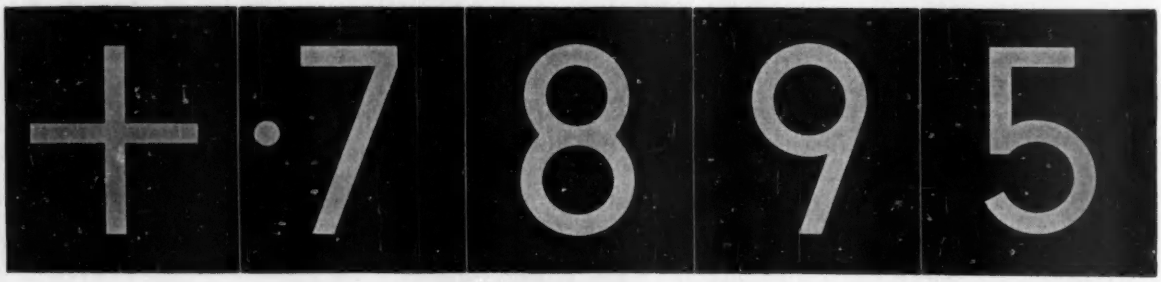
1. SINGLE-PLANE READOUT: KIN TEL digital voltmeters employ a simple projection system to present numbers on a readable single plane... no superimposed outlines of "off" digits... reduced possibility of error. Standard pilot lamps give extra long life.

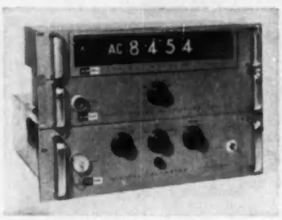
2. ADVANCED CIRCUIT DESIGN: Transistors employed where they contribute to performance and reliability... relay drive coils energized with DC as in telephone type service to provide long, trouble-free operation... automatic, continuous standard cell calibration. No electronic circuitry in readout allows easy remote mounting. Sensitivity control permits stable reading of noisy signals.

3. MANUFACTURING EXPERIENCE: KIN TEL has manufactured over 10,000 "standard cell accuracy" DC instruments on a true production line basis. Only by this method, by years of repeated manufacturing experience, by an over-all awareness of the accuracies and tolerances involved, is it possible to guarantee consistent accuracy and reliability... to assure real value for every dollar you invest.

4. NATIONWIDE APPLICATION ENGINEERING FACILITIES: KIN TEL has engineering representatives in every major city. An experienced staff of over 200 field engineers is always immediately available to help solve your application problems, provide technical data, or prepare a detailed proposal. Factory level service is available in all areas.

5. DESIDERATE SPECIFICATIONS (MODEL 401 DC DIGITAL VOLTMETER): *Display*... 4 digit with automatic polarity indication and decimal placement. Total display area 2" high x 7½" long, internally illuminated. Each digit 1⅛" high. *Automatic Ranges*.. .0001 to 999.9 volts covered in 4 automatic ranges. Sensitivity control provides least digit sensitivities of .1, 1, and 10 mv. *Accuracy*... 0.01% ±1 digit. *Counting Rate*...20 counts per sec., providing average balance (reading) time of 1 sec. *Reference Voltage*...Chopper-stabilized supply, referenced to an unsaturated mercury-cadmium standard cell. *Input Impedance* ...10 megohms, on all ranges. *Output*...Visual display, plus print control. Automatic print impulse when the meter assumes balance. No accessories required to drive parallel input printers. *Input*...115 volt, 60 cycle, single phase, approx. 75VA. *Dimensions*...Control unit, 5¼" high x 19" wide x 18" deep. Readout display, 3½" high x 19 "wide x 9" deep. *Weight*...Approx. 40 lb. *Price*... $2,450.





Model 402 AC/DC 4-digit

Model 401 DC 4-digit

Model 501 DC 5-digit

6. WIDE RANGE OF MODELS—ACCESSORIES—SPECIAL SYSTEMS: Versatile "digital building blocks" permit measurement of AC, ohms, ratios of AC and DC, automatic scanning of multiple inputs... 4- or 5-digit models. Preamplifiers increase digital voltmeter sensitivity to 1 microvolt DC, 10 microvolts AC. Buffers permit driving typewriters, tape punches and printers. KIN TEL's Special Products Department can design and manufacture digital instruments to meet special requirements... complete digital systems for data logging, missile checkout and automatic production line testing.

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

Write today for descriptive literature or demonstration. 5725 Kearny Villa Road, San Diego 11, California

the McGraw-Hill annual fall survey of capital spending, **manufacturing companies plan to spend $9,678 million in 1959, down 3 percent from 1958** (a 26 percent decline in 1958 capital spending is frequently blamed for some of 1958's disappointing control sales figures). **But not all industries are planning a cut. The rubber industry, for example expects a 20 percent boost; clay and glass companies plan to increase spending by 11 percent; and food and beverage processors will increase spending by 10 percent.** Capital spending plans as reported in the survey:

Spending plans

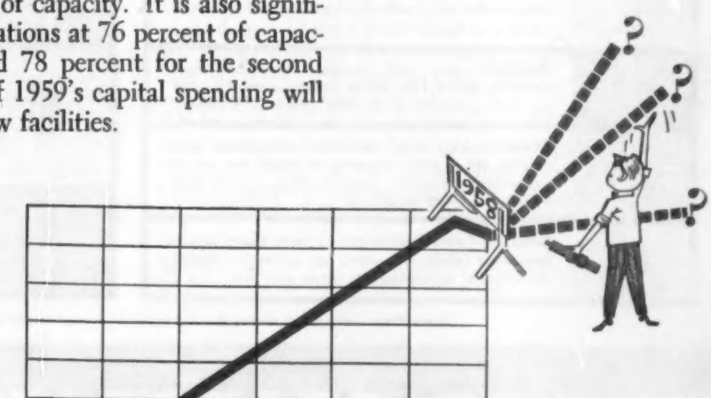
INDUSTRY	1957 Actual*	1958 Estimated*	1959 Planned	1958-59 Percent change	1960 Planned
Iron & steel	$1,844	$1,199	$1,043	−13%	$1,043
Nonferrous metals	980	510	398	−22	295
Machinery	1,275	1,025	1,031	+ 1	1,099
Electrical machinery	599	517	507	− 2	583
Autos, trucks & parts	1,058	646	672	+ 4	645
Transportation equipment (aircraft, ships, RR eqpt.)	544	408	355	−13	359
Other metalworking	942	727	737	+ 1	722
Chemicals	1,724	1,400	1,288	− 8	1,211
Paper & pulp	811	602	566	− 6	634
Rubber	200	136	163	+20	187
Stone, clay, & glass	572	404	447	−11	461
Petroleum refining	853	606	588	− 3	623
Food & beverages	850	737	813	+10	800
Textiles	408	264	229	−13	273
Miscellaneous Manufacturing	987	828	841	+ 2	720
ALL MANUFACTURING	$13,647	$10,009	$9,678	− 3	$9,655

* U. S. Department of Commerce, Securities & Exchange Commission, McGraw-Hill Dept. of Economics

Modernization ahead

The king-sized share of this money will go for modernization. The Federal Reserve Bank of Philadelphia, which just surveyed manufacturers in the Philadelphia metropolitan area and found they planned a decrease of 14 percent in spending plans, blames continued excess capacity for the cuts. "In the fourth quarter of 1958," says the bank, "firms (in the Philadelphia area) estimate they will be operating at 76 percent of capacity. It is also significant that manufacturers project operations at 76 percent of capacity for the first quarter of 1959 and 78 percent for the second quarter." This explains why much of 1959's capital spending will go for modernization rather than new facilities.

However, as CtE went to press, employment and activity indicators were still rising. **If the improvement in business continues, it is likely that capital spending plans will be changed—favorably—to keep up.** Industries to watch: steel, chemical, and petroleum.



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Control ENGINEERING JANUARY 1959

What the Editors See for '59

For the coming year, control engineers can expect that the magnitude and frequency of their opportunities (some might prefer to call them problems) will be shaped by the spending plans reported on pages 59-61, and by the advent of new-capability instrumentation and control system equipment (gear that can do jobs that couldn't be done before). CtE's editors expect that modernization plans will spur application in all phases of control systems engineering: measurement, test, transmission, data processing, control-decision, and actuation. But they look for the new-capability product activity to occur in these areas:

▶ Static controls–1959 will be a year of decision for static switching. When these devices were first introduced, their manufacturers expected that machine tool builders would be their biggest market. But the high cost of static control and the collapse of machine tool sales in 1958 practically enervated the market. In 1959, static controls will come into their own in an unexpected area: the control of complex equipment such as steel mills, blast furnaces, and automatic warehousing–instead of machine tools. As 1958 ended, one supplier brought in several orders for static control, each in the \$30- to \$40,000 range. In addition, in 1959 two major new suppliers will start marketing static control. One area, however, that needs work: the development of a satisfactory proximity switch.

▶ New power handling components will cause a lot of excitement in the control field in 1959. General Electric expects to have production of its solid-state-controlled rectifier under way by spring. Some control engineers feel this is the most significant component development in the control field in a decade. They believe it may revolutionize power handling techniques.

There will be considerable activity in the use of stepping motors. Now out of the laboratory stage, stepping motors offer some major advantages for digital actuation. Topp Industries has a 72-step device for machine tool control which makes accurate five degree steps with a repetition rate in excess of 6,000 steps per sec, will stop and reverse in a fraction of a sec.

Still a third trend to exact major interest is the continued increasing use of dc motors for control and the introduction of high-powered fast-reversing servos, servomotors capable of handling 1 or 2 hp.

▶ Computer-loggers–After scoring a round of introductory sales successes in 1958, the companies that offer computers for control will find their devices being used in 1959 primarily to learn more about processes that can be controlled by computers. Expect little closed-loop operation by computers in 1959; the emphasis will be on using computers and data loggers to find out more about processes in steel-making, petroleum refining, and other basic material production industries.

▶ Numerical control of machine tools is set for wider user acceptance. Most industry observers feel that machine tool sales dropped as far as they could in 1958, there will be nothing but improvement from here through 1960. One supplier plans a major sales effort to sell a point-to-point positioning system, an effort which should pay off in increased use of such control. The Topp Industries Micro-Path contouring system selling for only \$12,000 (see page 28) is a major breakthrough for contouring control, will result in the introduction of this kind of numerical control into industrial shops not subsidized by the military.

▶ Electronic process control–As 1959 gets under way, all those companies which introduced new electronic process control systems at the ISA show in September will have them in production. Look for electronic process control to gain 10 to 15 percent more of the control market than it had in 1958 in new process installations where air is not required in processing. Also, surprisingly, don't expect a drop in usage of pneumatic process control.

▶ Electronic display–Although practically all the money will be spent by the government, the area of dynamic display and high-speed printers will represent a market close to a hundred million dollars in 1959. The Air Force's SAGE, the Army's Missile Master, the Navy's dynamic surveillance display and the Federal Aviation Agency's air traffic control system rely heavily on electronic display of one form or another. Look for new competition for Hughes Aircraft's Memoscope; at least one other electronics company will be marketing a cathode ray tube that will retain a trace.

▶ Automatic test and inspection–Military suppliers have made some major strides forward with automatic test procedures, particularly on electronic equipment. Look for some of this to move into industrial production. The big advantage of 100 percent inspection of components–major reduction in trouble shooting costs in final inspection of the finished product–will be useful to consumer industries caught in a profits squeeze.

W. E. Vannah

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Sweep: 15 calibrated sweeps, 1-2-5 sequence, 5 μsec/cm to 0.2 sec/cm, accuracy ±5%. "Times-5" expander, all ranges. Vernier extends 0.2 sec/cm range to 0.5 sec/cm.

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Vertical Amplifiers: Identical A and B amplifiers, 4 calibrated sensitivities of 10 mv/cm, 100 mv/cm, 1 v/cm and 10 v/cm; ±5% accuracy. Vernier 10 to 1. Balanced (differential) input available on all input ranges. With dual trace, balanced input on 10 mv/cm range. Input impedance 1 megohm with less than 60 μμf shunt. Bandwidth DC to 200 KC or 2 cps to 200 KC when AC coupled. Internal amplitude calibrator provided.

Function Selector: A only, B only, B-A, Alternate and Chopped (at approx. 40 KC).

Horizontal Amplifier: 3 calibrated sensitivities, 0.1 v/cm, 1 v/cm, 10 v/cm. Accuracy ±5%. Vernier 10 to 1.

Bandwidth DC to 200 KC or 2 cps to 200 KC, AC coupled.

General: 5AQP1 CRT, intensity modulation terminals at rear, power input approximately 150 watts, all DC power supplies regulated.

Price: (Cabinet or rack mount) \$625.00.

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Applying the Systems Approach to WAREHOUSING

Automatic warehousing is now technically feasible—at a cost. How automatic a warehousing installation can be depends primarily on how quickly savings from automatic operation can pay off the extra cost. One way to determine this is to apply the systems approach. Here are five approaches to the warehousing problem, progressing in complexity from a simple manual system to a sophisticated computer-controlled layout.

R. J. MARLAND, General Electric Co.

The application of automatic controls to warehousing operations holds out promises of substantial improvements in efficiency and a reduction of arduous and tedious labor by the working force. Yet, of all portions of the manufacturing process, warehousing has resisted mechanization and modernization the longest.

One reason for this has been the difficulty in justifying economically a large investment in automatic equipment. Warehousing adds nothing to product value (in the theoretically ideal situation, product is shipped right from the end of the production line). Another factor is that every warehousing operation is different from any other. That tends to discourage standardization, or common solutions. Each warehouse has to be studied by itself to determine which parts can be made automatic—and justified economically—and which, if any, are to remain manual.

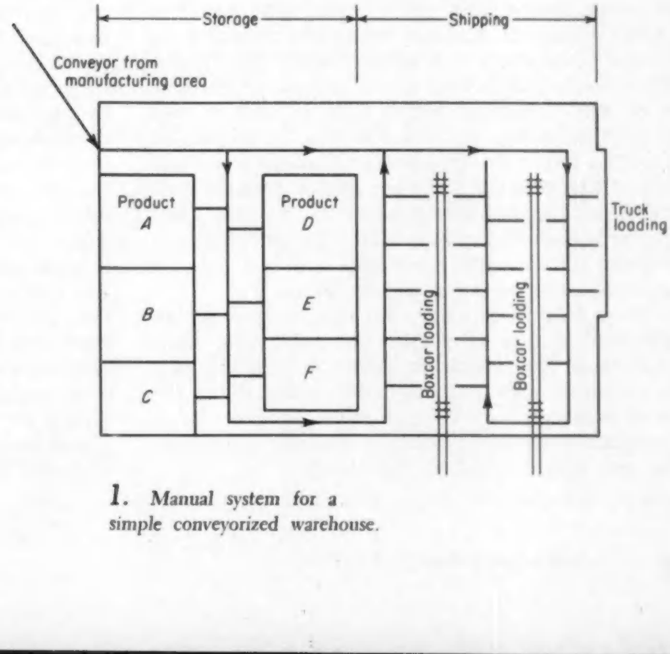
When the systems engineering approach is applied to the warehousing operation, the storage function is considered an integral part of the manufacturing process rather than as an unconnected tag-along operation at the end. The first step is to analyze warehousing into its basic functions. There are three: moving products into storage, knowing how many of each kind of product is on hand, and filling orders for shipment. To do these jobs, it is possible to plan a variety of systems with different degrees of automaticity, starting with a very simple one and evolving to a highly integrated automatic system. Here are five typical ones:

1. Manual system
2. Dispatch system
3. Sensing system
4. Automatic loading and unloading system
5. Automatic data logging

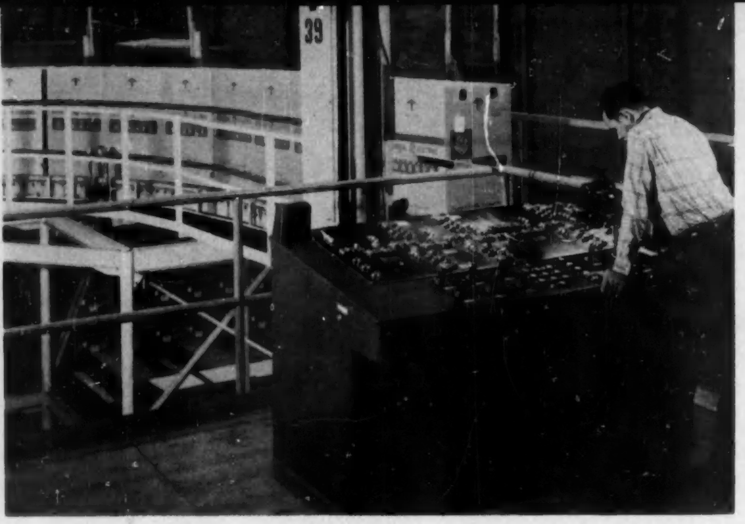
Choice of a system depends on such variables as size, quantity, and variety of products; number of orders to be filled per day; average size of order—number of items and variety; kind of containers in which product is packed; cost of automatic vs. manual equipment; and savings derived from automatic techniques. Depending on the application, one or more of the listed systems may be used.

Manual system

The majority of warehouses in operation today use a system in which all loading, unloading, and direction is accomplished manually. The usual lay-

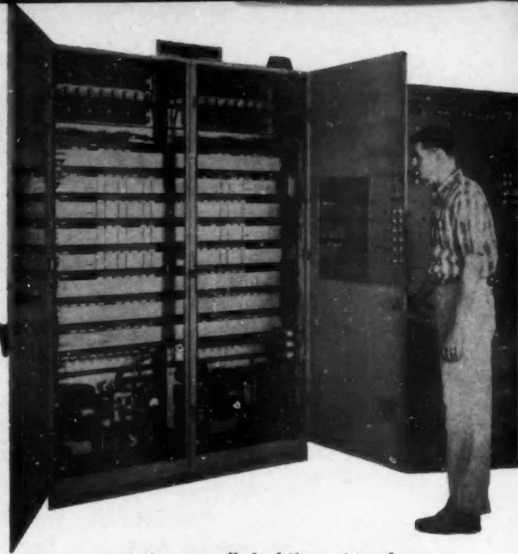


1. Manual system for a simple conveyorized warehouse.



2. *Dispatching system*

On an operator's console, dispatcher selects proper storage area for conveyor train as it enters the warehouse at GE's Appliance Park plant. Then . . .



. . . . static controlled shift register keeps track of the train as it moves through the warehouse. Graphic lines and indicating lights help maintenance personnel follow operations.

out is a simple conveyorized warehouse. Figure 1 is a typical example. Goods flow from the production area to any one of six storage areas over conveyors. At the proper storage area, they are removed and placed in bins, stacks, or on pallets with the help of a variety of manually-operated equipment, such as tow carts, roller conveyors, fork trucks, drag chains, overhead cranes, etc. On demand, goods are moved by the same equipment from the storage area to the shipping dock.

A clerical force has to prepare, by hand, production, shipping, and inventory records. Additional clerical effort correlates orders with inventory, prepares the order-picking lists.

Dispatch system

A first step in mechanizing a warehouse is to add a dispatch control that automatically directs incoming materials to the proper storage area. In such a system, goods from the manufacturing area first pass a dispatcher, who uses equipment ranging from simple pushbuttons to telephone dials to direct merchandise to the correct warehouse area. He may even use mechanical means such as location pins and guide vanes. In such a system the dispatcher inserts a pin in the tote box, at a point corresponding to that of a director vane located over the conveyor at the transfer points. As the tote box proceeds down the main conveyor, the pin physically engages the director vane and the box will be diverted into the proper storage area.

More frequently today, the preference is for an electrical system of similar principle using limit switches. The dispatcher locates a "dog" so that it engages a corresponding limit switch at the desired transfer point. When tripped, the limit switch energizes a solenoid to operate a mechanical switch or ram, which completes the transfer.

A more sophisticated system can be used if very few products are received or if large batches of similar products are manufactured for a long period of time. Here, the dispatcher transfers the products directly from a pushbutton console.

In one such system, automobile bodies are dispatched to any of five storage conveyors. This selection can be maintained for single or multiple units. The transfer system remembers the operator's instruction by means of sealed-in relays, mechanically-held relays, or static-switching relays and timers. Limit switches assure completion of a transfer before the operator's next signal can change the transfer set-up. But production rates and total number of transfer points place severe limitations on the use of such an arrangement.

Shift registers

A more sophisticated system with greater flexibility relies on the shift register. In the shift-register system, each transfer point is assigned a zone number and a corresponding binary code signal. As a unit or group of units passes the dispatcher, he selects by pushbutton the destination of products. The dispatch signal goes into the shift register, where it is maintained on a "first-in, first-out" basis. As the first units approach the first transfer point, the dispatch signal is compared with the transfer-point code signal. If the signals correspond the transfer is made and the dispatch signal is canceled out of the shift register. If they do not correspond, the unit proceeds down the main conveyor to the next transfer point and another comparison made. Limit switches are used to prevent more than one unit or group of units from being in a given conveyor zone at any one time. The control will automatically search ahead, and if the next main conveyor zone is empty, the unaccepted unit is allowed to proceed;

thus full capacity of the system is utilized at all times.

Static-switching devices are generally used in shift-register systems because of their characteristic flexibility, long life, low maintenance, and memory. The diagram below provides a schematic look at how the shift register works at GE's Appliance Park warehouse.

Punched-tape techniques can also be employed in a dispatch control system. The dispatcher codes, by pushbutton, product identification and/or storage location, as in the previously described system. But the code is now registered on a punched tape. As the product approaches the first transfer point, a limit switch indexes the tape so that the corresponding punched code will be read by the tape reader. Acceptance or rejection is accomplished by preprogramming the transfer-point control to accept specific codes. If an item is not accepted, its identifying code is punched on a second tape, which then controls the items on the second section or in the second zone of the main conveyor. The comparison process repeats at the second transfer point, and if rejected the code is transferred to a third tape. The total number of punched tapes is one less than the total number of transfer points. The last storage area catches all codes passed by the preceding transfer points.

Magnetic tape can be used instead of punched tape. The system used is the same except for the tape, which may be continuous between printer and reader in each zone. Because it is continuous, the tape is magnetically cleaned after reading and before new codes are imposed upon it.

In a modification of the tape system, product identifications and/or location codes are preselected. For example, if a production line is running only one product for a considerable length of time, a preselected code is punched into the tape system as each item leaves the manufacturing area to enter the warehouse system.

Sensing system

Dispatching systems work with a limited number of products and transfer points. Sensing systems are less confining.

In its simplest form here's how a sensing system works. The dispatcher places a punched or coded card in the same physical location on each item as it passes. Fingers or photoelectric sensing units are located at each transfer point. The sensing unit control is preprogrammed to search out all items bearing a specific code or group of codes. The desired units are accepted for storage and a transfer made, while the rejected units continue down the main conveyor to be sensed at the next transfer point. Depending upon the ultimate intent of the sensing system, product identification or physical location, or both, can be coded and detected.

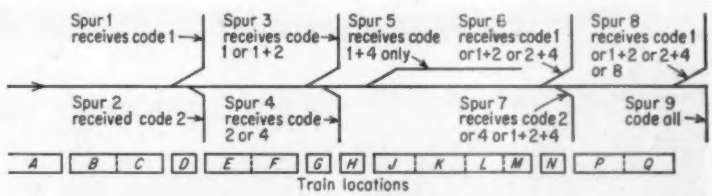
In some cases, it is sufficient to identify products and warehouse them in terms of their physical size. This can be done by photoelectric or mechanical means at the transfer points. Acceptance or rejection for storage is made by detecting one of the parameters. But this type of sensing system has limited use in today's warehouse operations.

Coded cards can be used to direct products to storage. In one system, the products are transported in uniform trays. The dispatcher places a card coded for the desired storage area on the side of each tray as it passes. And a card reader is located at each transfer point.

Mechanical fingers are physically located in the card reader to correspond with the acceptable coded cards for the particular transfer point. These brush the cards, making electrical contact as the trays pass. Whenever an acceptable code is detected the transfer mechanism is initiated.

A more applicable sensing system uses magnetic ink. By preprinting the carton for each kind of product with visible or invisible magnetic ink in the same physical location, the product can be detected and identified as it enters the warehouse area. The preprinting usually is in the binary code form, which can be readily detected by a sensing unit. In practice, the code is placed on all items at the same height above the conveyor, or the same distance in back of the leading edge of the carton, to facilitate accurate detection. The transfer-point control is preprogrammed as previously described to accept a specific code or group of codes for storage.

A sensing system then performs the same function as a dispatch system; the difference is that it senses



Spur selected	Binary code for four channel shift register				Train locations	Switch operated
	8's	4's	2's	1's		
					A	None
1	0	0	0	1	*B–C*	1
2	0	0	1	0	*D*	2
3	0	0	1	1	*E–F*	3
4	0	1	0	0	*G*	4
5	0	1	0	1	*H*	5
6	0	1	1	0	*J-K-L-M*	6
7	0	1	1	1	*N*	7
8	1	0	0	0	*P–Q*	8
9	1	0	0	1	—	—

One line diagram shows operation of the memory and shift register system.

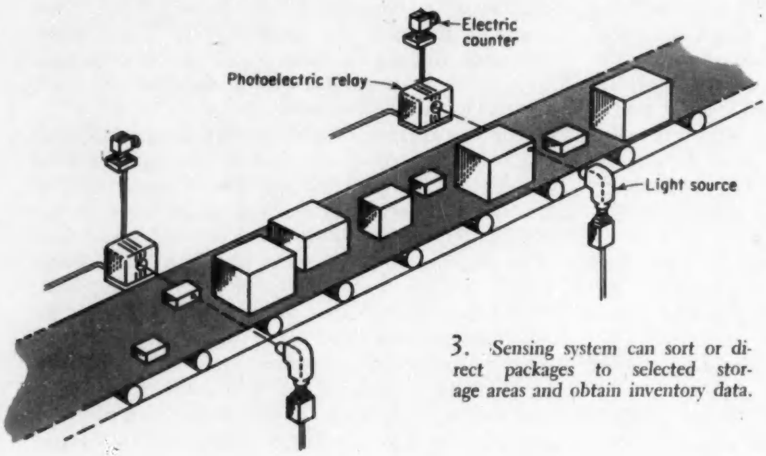
product identification and so eliminates the necessity for an identification code signal to be memorized by the control. All material is dispatched or preprogrammed to a specific storage area. Loading, unloading, and record reporting are still manual.

Automatic loading . . .

The next step in mechanization eliminates the manual loading and unloading of the products. Consider two different types of storage areas. In one, there is a separate point of exit to the shipping area; in the other, the material in storage must be routed to the shipping area utilizing the same facilities which brought the material into storage.

If products enter at one location and go to shipping at another location a single gravity-type conveyor can feed the storage area. The transfer conveyors of the dispatch or sensing system deposit products in the elevated end. The items then proceed down the conveyor in a "first-in, first-out" basis until retarded by a holding device. This mechanism can be released locally or from a remote position to allow any desired number of a product to be pulled out of storage by a powered conveyor and transported on to the shipping area. This method is limited because storage capacity is limited. It uses floor space poorly; and warehousing frequently requires storing more than one kind of product in a particular storage area.

One way out is to rack the gravity feed conveyors one above the other; this way, it is possible to store a larger number of products and to use the floor space more efficiently. Automatic unloading of the transfer conveyor is then accomplished by a hydraulic or pneumatic lift, suspended fork lifts, cranes, or other material handling devices which will accept an electrical signal. Complex limit switch systems, elevator floor call systems, and numerical positioning control systems can be used to position an unloading device at a preselected location.

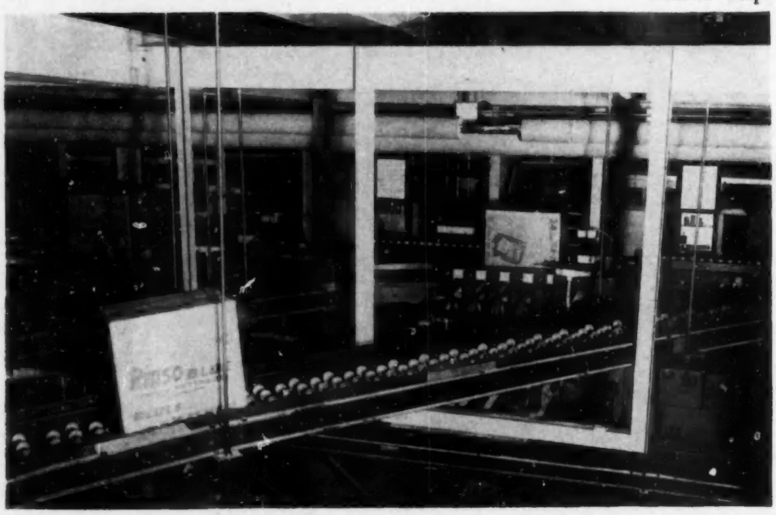


3. Sensing system can sort or direct packages to selected storage areas and obtain inventory data.

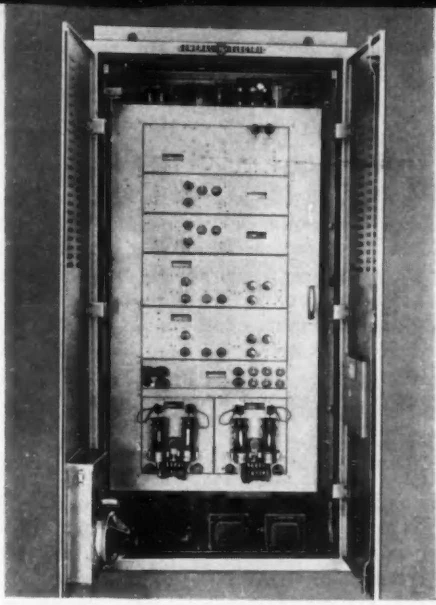
. . . and unloading

The techniques of the dispatch or sensing system can be extended to unloading. An item enters the unloading device accompanied by an identifying code signal, or capable of being sensed for an identifying code signal. This identifying signal is electrically compared with a storage program previously established to control the movements of the unloading device. The unloader then delivers the item to the proper storage conveyors as directed. By using "duplex" controls, regulating horizontal as well as vertical motion of the unloader, the designer can increase storage capacity.

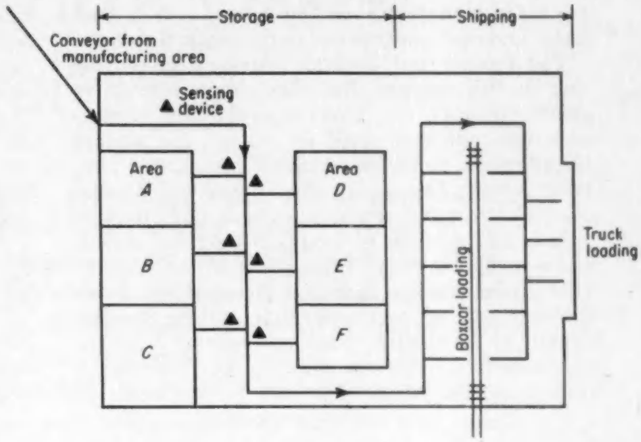
Sensing system at work in soap warehouse. Packages here are sorted by identifyinig marks. Photoelectric cells operate transfer mechanisms. —Lamson Corp.



Unloading the storage conveyors is not as complex a problem as unloading the transfer conveyors. The loca-



4. *Numerical positioning control panel can be used to direct automatic loading and unloading equipment. Input media can be punched tape or cards, decade switches, or telephone dials.*



Layout of an automatic loading and unloading system that uses the same materials handling equipment for both operations.

tion of the product is known, so an item does not have to be identified again as it leaves storage. Powered take-away conveyors are used from each elevation. Generally a single conveyor extending the entire width of all the storage conveyors on each elevation is used. With such an arrangement, the operator releases at one time all items stored on one elevation. The degree of automatic operation in the unloading area varies greatly, depending on economic considerations, the method of recording data, and the method of inventory control.

In the layout above, there is shown a similar system to the one just discussed, with the exception that the material storage is routed to shipping by means of the same facilities which brought it into storage. In such a system, large tote boxes, pallets, and other large, heavy items are stored in racks or pigeon holes.

Both of these automatic systems use the same type of material-handling unloading equipment and unloading controls to unload the transfer conveyor and place the items in storage. The big difference is in withdrawing goods for shipment.

A different sequence of operations is required in a withdrawal cycle if the same equipment is to be used. Once the cycle is set up, the storage program is electrically directed to recall a specific item from storage. In the layout shown, products can be recalled from any of the storage areas independent of the other area operations. If it becomes necessary to reverse the direction of the transfer conveyor, storage and recall could not proceed at the same time, and separate specific times would have to be set up to receive and to withdraw goods.

By combining the automatic loading and unloading material-handling equipment with the dispatch or sensing systems a higher degree of automatic control is attained. Data logging for production, shipping, and inventory control is still being done manually.

Data logging

To determine "how many of what product to warehouse" and "how many of what product to produce", accurate and reliable production, shipping, and inventory records are required. A large clerical force can be employed to provide this statistical data; or it can be gathered rapidly and accurately, and be almost instantly available, by applying automatic data logging equipment.

Here is a simple inventory system, usable with a dispatching system, which illustrates the basic principles involved in warehousing data logging. The dispatcher punches the product identification and storage location of each item into a card, which is duplicated. One copy remains with the dispatcher while the other accompanies the item into storage. The dispatcher's cards are sorted by item, totalized and printed out to give an accurate record of production. These cards are searched to locate a specific item in the warehouse to fill a specific order. The cards selected to fill the order are then sorted by physical location to minimize the order picker's work.

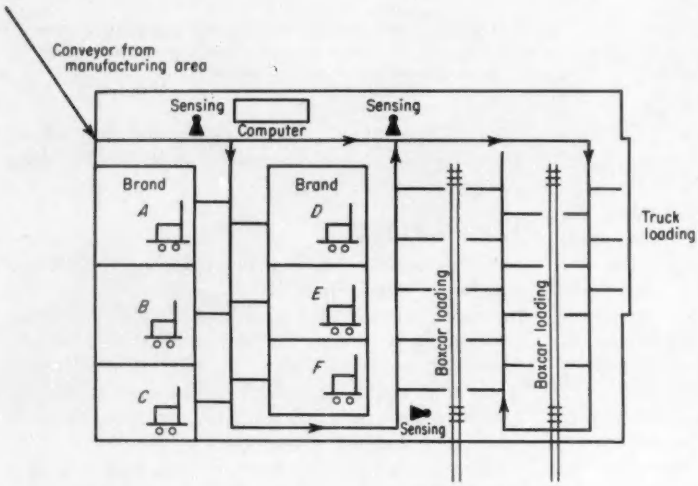
The duplicate card which accompanied the item into storage is used for identification and is removed in the shipping area. A shipping list is made quickly by printing out the cards received in shipping for all items loaded into a car or trailer. By sorting, totalizing, and printing out all the cards of shipments made in a given period of time, composite shipping records are made available.

In this example, exact inventory knowledge is stored in the dispatcher's card deck at all times.

These inventory, production, and shipping records are made available by adding a card punch, card sorter, and card reader to one of the dispatch systems.

The sensing and dispatch systems also provide data in this manner. But they can provide it in another manner, too. Every time the tape or magnetic ink code is accepted for storage, the product identification is already available in a coded electrical signal. This signal can be read out directly on an electric typewriter to provide inventory records.

It is also possible to combine a sensing system and a small computer to produce inventory records. One sensing device is located at the warehouse input (because part of the production can be diverted directly to the shipping area), and another identifies all products entering the shipping area. Instead of reading out the signals from each sensing head, all the signals are fed into the computer. The computer automatically correlates the information, adding inputs to the warehouse and subtracting shipments on a per item basis. This system makes inventory records available instantly.



5. *As a final step a computer completely controls the material flow in the warehouse, using as building blocks the sensing system, automatic loading and unloading, and data logging.*

As a final step, a computer applying the concepts of sensing, automatic loading and unloading, and data logging completely controls the material flow in a warehouse and provides instantaneous inventory data. Since products can be identified automatically, the entire operation functions automatically. The program for loading and unloading, however, must be predetermined; thus incoming items are routed to preselected storage areas and outgoing items are programmed by translating the order into the system code.

It is difficult to set down even general rules as to which kind of system or combination of systems to use for a particular type of product. Each application must be reviewed from a product, process, and economic viewpoint before the proper system can be determined. In general, the cost of automatic control will be proportionate to the total amount of information the system will be required to handle and store. Thus every effort should be made to minimize this information: cartons of like items can be handled piggy back, in large groups, or palletized and handled as one unit of memory storage.

Surge capacity—an analogy

To determine where surge capacity is needed is the true job in warehousing. The size of surge capacity depends on such factors as product diversity, manufacturing cycles, manufacturing rates, customer demand rates, and the distribution patterns of the products, and all these must be correlated. A study of the manufacture of children's wagons shows how complicated this can be. A wagon can be made in several sizes, have several colors, have several wheel colors, etc.; thus, to warehouse a finished assembled product entails the storage of a large number of different kinds of products. But by warehousing the individual wagon parts, this number can be greatly reduced. Complete unassembled wagons are then packaged upon receipt of orders. Not only has the number of items been reduced, but assembly and packaging labor is not tied up in inventory.

This analogy can be carried back a step further into the process. If unpainted wagon bodies, wheels, handles, etc., are stored, the warehouse problem is further minimized. Painting can be scheduled in terms of orders if the time cycle allows. In general, a compromise between storing finished and "parent" products will yield savings in those industries where such processes are applicable.

When the warehouse requirements are clearly defined, the benefits of any new system must be evaluated against an existing method of operation. Probably the largest single area of savings available to the manufacturer will be in the rapid turnover and corresponding reduction of inventory of products made possible by the application of automatic systems.

By providing a warehouse system which can rapidly handle products with a minimum of direct labor and by providing management with accurate order, production, shipping and inventory records, the warehouse operation can be optimized to provide the maximum return on invested capital.

Bringing the HELICOPTER Under Control

THE GIST: The typical helicopter is dynamically unstable in hovering flight, and therefore needs automatic control. Unfortunately, dynamic analysis of the helicopter is difficult because of its many possible oscillatory modes (there are some 15 important degrees of freedom involved in the typical helicopter), as well as the coupling between these modes. Here is a method of analysis that considers these modes separately, using root locus techniques, and adds the effects of coupled modes a step at a time. The method is outlined for the longitudinal channel of a control system that will satisfactorily stabilize and hold a helicopter over a fixed earth reference.

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Compared to an airplane pilot, the helicopter pilot has considerable latitude in choosing a flight path. This is due principally to the fact that the vertical and horizontal motion of the helicopter can be controlled independently, from four controls that govern position and attitude in space. The main thing in this respect is the rotor, and the main control component of the rotor is the swash plate. The rotor blades are attached to the swash plate's rotating part by linkages that permit the swash plate to control blade pitch angles at all azimuth positions. The nonrotating part is connected to the pilot stick by other linkages, Figure 1.

A tilt of the swash plate (called cyclic control) is equivalent to changing the pitch of the blades as a function of their azimuth positions. A vertical motion of the swash plate (called collective pitch control) changes the pitch of all the blades simultaneously, independently of the blades' azimuth positions.

So-called articulated blades are hinged. They are thus free to flap in and out of the plane of rotation, and usually to lag or lead in this plane, too. The blades of an articulated rotor in rotation will cone up until equilibrium between the lift and centrifugal forces is reached. The plane formed by the tips is called the tip-path plane; its tilt in the lateral or longitudinal direction is controlled by the tilt of the swash plate. Since the rotor force (thrust) is approximately perpendicular to the tip-path plane, the pilot essentially controls the modes of the air-

* The actual control work from which this article evolved was done by the authors while they were with the J. B. Rea Co.

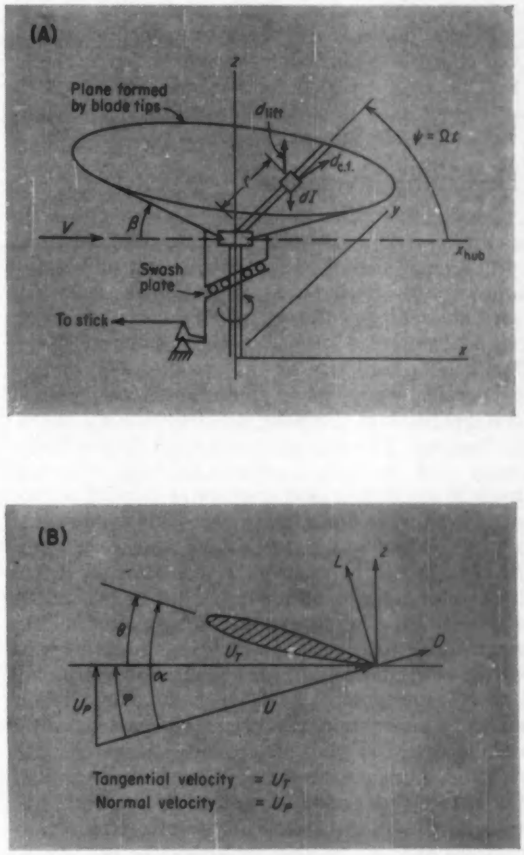


FIG. 1. A—schematic of single-blade rotor, showing swash plate, and forces acting on blade element at radius r; B—section of rotor blade showing development of lift and drag forces.

craft by tilting this rotor thrust force in the direction that he desires to go.

Specifically:

Vertical control is achieved by increasing the pitch of all the blades simultaneously, by means of the collective pitch control (obviously throttle control, one of the four independent controls, is related very closely to the collective pitch control).

Longitudinal and lateral control for a single rotor helicopter is achieved by changing cyclic pitch to tilt the rotor thrust.

Directional control of a single rotor helicopter is usually achieved by controlling the pitch (by foot pedals) of the anti-torque tail rotor, which permits the pilot to create controlling moments about the vertical axis.

In this article two types of lifting rotors are discussed: 1) articulated rotors, in which the blades are attached to the hub by hinges, free to flap up and down; and 2) rigid rotors, in which the blades are connected rigidly to the shaft. The articulated blade configuration is the more popular because the hinges alleviate the blade root stresses that are present when the blade is rigidly attached to the hub.

In the following discussion of helicopter stability and controls the helicopter dynamics are considered first, as an open loop (or forward loop); then the helicopter plus stabilization controls are presented as a closed-loop system.

Helicopter dynamics

Methods developed by the servo-engineer for analyzing automatic control systems have been used with a great deal of success in studying the stability and control of fixed-wing airplanes; but they have presented some problems in obtaining solutions to the helicopter's dynamics. This is primarily due to the basic complexity of the equations of motion, particularly when they include the effects of lateral and longitudinal coupling and the rotor's degrees of freedom. The helicopter dynamics can be looked upon as a two-body problem, i.e., the rotor and fuselage (or body). The number of degrees of freedom, even when considering rigid body components, is large. The body has its six motions, three translational and three rotations. And the fully articulated rotor blade has three more, due to the motion about its flapping and lagging hinge and the control of the blade pitch about its feathering axis. However, the motion about the lag hinge is usually heavily damped to prevent a deleterious oscillation, making this motion of little consequence in the stability analysis. And on the larger helicopter, the blade feathering control inputs are usually applied through an irreversible boost, thus imposing the stick fix condition (control not free to seek a position dependent on the aerodynamic and inertia forces feeding back from the control surfaces).

The dynamics of the helicopter are to be illustrated by treating progressively the rotor, rotor plus body mass and inertia, rotor plus body mass and aerodynamics, longitudinal and lateral coupling, etc. The various degrees of freedom are added by adding linear differential equations to the systems equations.

Rotor dynamics

An understanding of rotor dynamics is basic to the overall stability and control problems of the helicopter. The rotor provides the lift, the control, and the propulsion force for the helicopter (while the hub is subjected to large stresses from a rotor blade which is experiencing between 300 to 400 g's of normal acceleration at the tip).

To begin with, picture a shaft rotating at an angular velocity Ω, with swash-plate mechanism and blade attached. The orientation of the shaft axis is considered fixed in space (i.e., shaft is not free to pitch or roll) but the rotor and shaft can be moved forward at a constant velocity, V, along the x axis, Figure 1.

The instantaneous flapping angle β for a blade hinged at the hub is expressed by the equilibrium of moments about the flapping hinge. Equating the aerodynamic moments and inertia moments about the hinge gives the required relationship:

$$\underset{\text{(aerodynamic)}}{\int_0^R r\,dL} = \underset{\text{(centrifugal)}}{\int^R r^2\,\Omega^2\,\beta\,dm} + \underset{\text{(inertia)}}{\int_0^R r^2\,\ddot{\beta}\,dm} \qquad (1)$$

In the absence of the forward wind velocity, hovering flight, Equation 1 becomes linear (assuming small perturbation theory) with constant coefficients:

$$\ddot{\beta} + \frac{\Omega}{8}\,\gamma\,\dot{\beta} + \Omega^2\,\beta$$

$$= -\frac{\Omega^2}{16}\,\gamma\,B_1\,[\sin\,(\Omega - \omega)\,t + \sin\,(\Omega + \omega)\,t] \qquad (2)$$

The bracketed term arises because the swash-plate input to the blade is in the nature of a suppressed carrier; if a sinusoidal input is assumed, the input frequency ω modulates the carrier frequency, here the rotor angular frequency of rotation, Ω.

The term γ is known as Lock's mass factor, a nondimensional ratio between a moment proportional to the aerodynamic blade loading and the blade moment of inertia about the flapping hinge. The factor is significant in rotor design, for it provides a composite identification based on many of the rotor parameters:

$$\gamma = \frac{\rho\,ac\,R^4}{I_b} \qquad (3)$$

and ranges from 5 to 15 for most helicopters. ρ, a, and c are constants defining the air density, lift curve slope, and blade chord.

The second-order system denoted by Equation 2 for the hovering rotor has a damping ratio of $\gamma/16$ and a natural frequency of Ω. Thus, for the average helicopter rotor system the damping ratio will be less than critical. The input contains two frequencies, $(\Omega-\omega)$ and $(\Omega+\omega)$, both near the natural frequency of the rotor for $\Omega >> \omega$. The cyclic re-

sponse in flapping β has a 90-deg phase shift with respect to swash-plate input, since the input frequencies are near the natural frequency of the rotor, Ω. In other words, if the system is excited by a swash-plate displacement with the maximum and minimum occurring in the lateral position, the β response oscillates in the fore and aft or longitudinal direction, which is analogous to gyroscopic motion.

Since the higher harmonics of flapping are successively about one-tenth of the previous harmonics, they can be assumed negligible, and the rotor can be treated as a body with the rotating blade forming a cone having as a base the plane of the tips. This assumes the flapping motion to be given by the constant and first harmonic terms of a Fourier series:

$$\beta = \beta_0 - a_1 \cos \Omega t - b_1 \sin \Omega t \qquad (4)$$

Substituting this assumed solution of β into the flapping equation (2), and equating to zero the constant, cosine, and sine moments component of the resulting equations, produces a matrix which yields considerable information about the dynamics characteristic of the rotor. For example, the longitudinal response of the tip-path plane is represented by the a term in the equation for which the sine term equals zero:

$$\Delta_1 = s + \frac{\gamma\,\Omega}{16}$$

with a time constant $\tau = \frac{16}{\gamma\,\Omega}$ (5)

Assuming a typical helicopter rotor with a blade mass factor of $\gamma = 10$ and an angular frequency $\Omega = 21$ rad/sec, the time constant τ equals 0.076 sec. The rotor time constant is thus small compared to the rotor's period of rotation ($\cong 0.3$ sec) and is considered fast compared to the pilot's input.

The more complete expression for the rotor dynamics involves lateral and longitudinal coupling, with a characteristic equation of the fourth order having the same damping rates of $\gamma/16$ associated with a high and low natural frequency. For the typical rotor, the roots become

$$\Delta_2 = (s + 13.1 \pm j\,4.80)\,(s + 13.1 \pm j\,39.2) \qquad (6)$$

These roots are displayed on the s-plane in Figure 2A for both Δ_1 and Δ_2.

The frequency response relating the longitudinal

FIG. 3. Diagram showing important relationships (longitudinal control) for rotor with hub displaced from helicopter c.g. by distance h. Vertical component of thrust T, minus W, produces vertical acceleration. Horizontal component of T, minus drag D, produces horizontal acceleration.

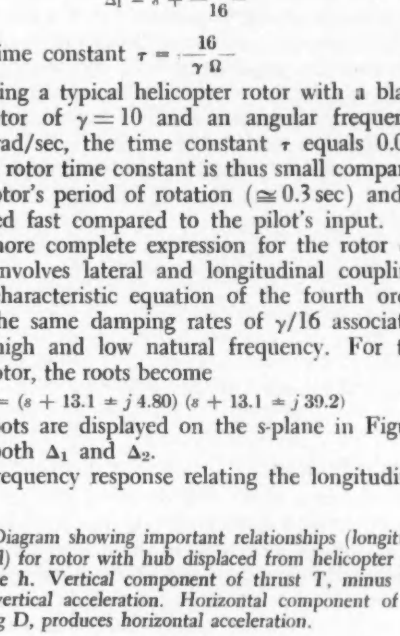
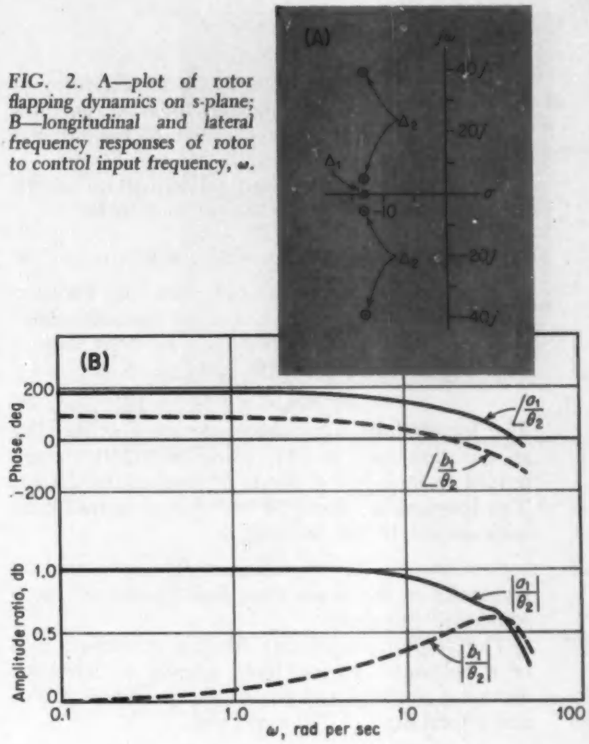


FIG. 2. A—plot of rotor flapping dynamics on s-plane; B—longitudinal and lateral frequency responses of rotor to control input frequency, ω.



and lateral tilts, a_1 and b_1, of the rotor plane to a longitudinal cyclic input, θ_2, is plotted in Figure 2B.

This plot makes it plain that a hovering rotor is symmetrical in longitudinal and lateral motions: a longitudinal response to longitudinal input is the same as a lateral response to a lateral input. The flapping rotor makes a good positioning device, as can be seen by the flat response (up to 10 rad/sec) in amplitude and phase (Figure 2B). The quadrature transfer function of the rotor, the lateral response to longitudinal input, appears to be that of an ideal differentiator for the lower frequencies in that the phase is 90 deg and the amplitude is directly proportional to the frequency. This pattern is modified slightly at the moderate advance ratios due to the dissymmetry of the air velocity for the advancing and retreating blade.

Hovering helicopter

Up to here, the discussion has presented the instantaneous equilibrium relationships of the articulated rotor blade without body or shaft motion in linear translation or pitching. It is a good first-order approximation for the hovering helicopter to neglect the aerodynamic forces acting on the fuselage, leaving gravity the only body force, Figure 3.

Consider the motions of the helicopter to be made up of body horizontal translation μ_x, body pitch α_1, and forward tilt of the rotor, a_1. The most elementary case would be a free flapping rotor with body c.g. coincident with the rotor hub ($h = 0$). The horizontal forces are composed of the horizontal

rotor force, the H force, and the inertia force of body and rotor. The horizontal force of the rotor includes the horizontal component of the lift and the rotor drag.

The equation for longitudinal translation of the helicopter from Newton's law of motion is

$$H_{s_0} = M \ddot{x}_{cg} = - M \dot{\mu}_x \Omega R \quad (7)$$

Having the c.g. located at the rotor hub excludes any of the rotor forces from creating moments about the body c.g. in pitch. The only moment then is the body moment of inertia, I_y:

$$I_y \alpha_1 s^2 = 0 \quad (8)$$

The longitudinal rotor moments are described by an equation such as (1), where moments are extended to include the effects of forward translation. The longitudinal input to the system is measured with respect to the horizon, or

$$\theta_2 = B_1 + \alpha_1 \quad (9)$$

where B_1 is the swash-plate input measured with respect to the shaft.

The resulting equations for the simplified case of a helicopter having three degrees of freedom, assuming the typical rotor of the previous section and a total mass of 200 slugs, yield

$$\Delta_3 = I_y s^2 (s + 13.07)(s + 0.0346) = 0 \quad (10)$$

Note that the system has the stable, highly damped aperiodic motion of the rotor, a pair of neutrally stable roots, and a slightly damped aperiodic mode. This elementary case does not represent the stability of the usual helicopter configuration, but it serves to illustrate a limiting case in which at best the helicopter can have neutral stability with the c.g. located near the hub. This is more representative of a rotor with c.g. near the hub, such as a flying platform (or rotor cycle) or a toy rotor. Since these examples usually have nonarticulated blades (blades fixed at hub instead of hinged), this case ($h = 0$) was expanded for a rigid rotor. The rotor moments are then transmitted to the body because the blade is not free to flap, and $a_1 = -\alpha_1$. The rigid blade characteristic for $h = 0$ was

$$\Delta_4 = \left(\frac{I_y}{I_b} + \frac{b}{2}\right)(110{,}000)(s - 0.0164 \pm j\,0.400) \times (s + 3.24) = 0 \quad (11)$$

Contrary to popular belief, the fixing of the blades to the hub does not necessarily produce a stabilizing effect. For a helicopter having rigid rotors the vertical location of the c.g. has little effect on the stability. To verify the results more fully the example was expanded to include the coupled motions about the pitch and roll axes; the divergence rate of the longitudinal unstable mode then was found to be double that given by Equation 11 (time to double $T_a \approx 21$ sec, instead of 42 sec as above).

In the more conventional helicopter design of Figure 3 (articulated blades with the body c.g. offset a distant h below the hub), the problem is to include the moment created by rotor forces acting on moment arms, i.e., the moment due to the offset h and possibly the offset e of the flapping hinge (hinge located a radical distance from the hub). Revising Equation 9 to include these offset moments gives

$$H_s h + T_s h \alpha_1 + \frac{eb}{2\pi} \int_0^{2\pi} \frac{1}{\Omega} F_s \cos \Omega t \, d\Omega t = - I_y s^2 \alpha_1 \quad (12)$$

where F_s is the vertical shear force at the flapping hinge and T_s is the vertical component of rotor thrust. If the typical helicopter is assumed to have a three-bladed rotor with a 24-percent c.g. offset ($h/R \times 100$) and a 3-percent hinge offset ($e/R \times 100$), the pitch transfer function for hovering flight becomes

$$\frac{\alpha_1}{B_1} = - 0.080 \frac{(s - 0.0011)(s - 22.5)(s + 50.7)}{\Delta_5} \quad (13)$$

where $\Delta_5 = \underbrace{(s + 0.970)}_{\text{longitudinal aperiodic}} \times \underbrace{(s + 13.1)}_{\text{rotor damping}} \times \underbrace{(s - 0.110 \pm j\,0.44)}_{\text{longitudinal unstable}}$

Here the characteristic equation contains the rotor lag ($s = -13.1$), which approximates the rotor characteristic of Equation 5, and the three roots near or at the origin in the characteristic of Equation 10 are driven away from the origin. The unstable pair is typical of most hovering helicopters. Through variation of the parameter h (vertical offset of c.g.), considerable change is produced in the characteristic of the helicopter dynamics (compare Δ_3 with Δ_5); however, the opposite is true for the rigid rotor design in that the vertical location of the c.g. (above or below the hub) has little effect upon the dynamic characteristics for $h < R/2$.

For a set of equations containing the lateral degrees of freedom, the only difference in the matrix is the body moment of inertia—everything else is symmetrical in hovering flight. The transfer function in roll (α_2) of a helicopter with $I_y/I_x = 5$ is:

$$\frac{\alpha_2}{A_1} = 0.352 \frac{(s - 0.0011)(s - 22.5)(s + 50.7)}{\Delta_6} \quad (14)$$

where

$$\Delta_6 = \underbrace{(s - 0.045 \pm j\,0.575)}_{\text{lateral unstable}} \times \underbrace{(s + 9.91)}_{\text{rotor damping}} \times \underbrace{(s + 4.33)}_{\text{lateral aperiodic}}$$

Forward flight

In forward flight the dynamic stability of the helicopter with horizontal tail surface tends to improve through a decrease in the divergence rate, and the negative damping is less in the dominant modes. A decoupled pitch transfer function in forward flight ($\mu_0 = 0.22$) for the sample helicopter is:

$$\left.\frac{\alpha_1}{B_1}\right|_{\mu = 0.22} = \frac{0.0833 (s + 0.025)(s + 0.828)(s - 13.5)(s + 71.5)}{\Delta_7} \quad (15)$$

The factors for the characteristic Δ_7 are

$$\Delta_7 = (s - 0.0292 \pm j\,0.374)(s + 1.065 \pm j\,0.326)(s + 10.1)$$

The damping factor of the unstable mode is lower

than in Δ_5—meaning that the time to double amplitude has been reduced. The mathematical model for the forward flight case includes one more degree of freedom than the corresponding hovering case. This added degree of freedom is the vertical mode since the flow over the rotor approaches that of an airplane wing in forward flight; as in airplane flight, the vertical degree of freedom is important. Figure 4 compares the characteristic poles and the pitch frequency response for the helicopter and a typical airplane.

Helicopter control system

The preceding sections discussed the derivation and formulation of the general equations of motion of a helicopter. The separation of these general equations into "control mode" equations opens the way to conventional servomechanism analysis techniques for helicopter automatic control design studies.

The root-locus method of stability analysis will be used to demonstrate the possibilities and results of typical types of feedback that can be used in designing an autopilot or an automatic stabilization system. The controlled helicopter will be considered to have the form of the general closed-loop system, Figure 5, in which the forward transfer function, $\mu(s)$, is the transfer function of the helicopter. Since the poles of a closed-loop system determine its dynamic response to an arbitrary input, the servo problem consists in determining a β (s) that will give the desired poles to the overall system; i.e., the choice of the feedback shaping determines the locus of roots that satisfy the expression

$$1 + \beta(s)\,\mu(s) = 0 \tag{16}$$

Consider as μ (s) the pitch transfer function of Equation 13; in this equation the roots next to the origin are of greatest concern since the damping and frequency are low and the roots describe the most dominant modes as seen by the pilot. The effect of the fast rotor mode is reflected in the new gain constant calculated for the forward-loop transfer function of the helicopter:

$$\frac{\alpha_1(s)}{B_1(s)} = \frac{6.96\,(s - 0.0011)}{(s + 0.970)\,(s - 0.110 \pm j\,0.44)} \tag{17}$$

Figure 5 is the general block diagram for the longitudinal control mode, where the feedback function is of the form $K_\theta\ (N_\theta/D_\theta = K_\theta\ (s + k)$.

The sensing element for the pitch angle could be

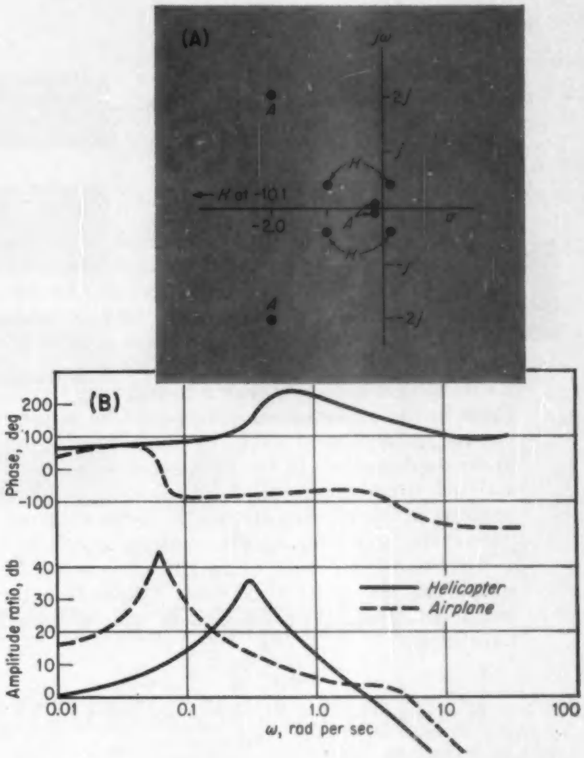


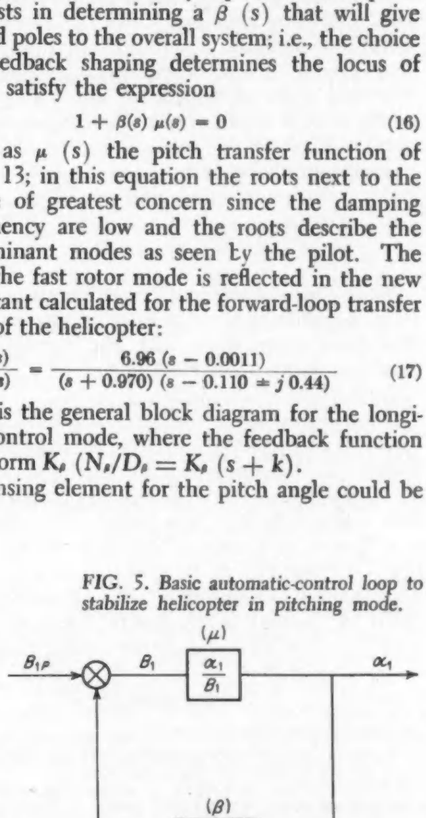
FIG. 4. Comparison of typical airplane and helicopter pitching modes in forward flight. A—s-plane plot; B—frequency plot.

a position gyro providing a signal proportional to pitch angle. This signal is shaped according to β (s) and then added to the pilot's control signal to form the error signal, which in turn provides the input to the swash plate.

The plot of Figure 6 describes the varying locus paths as a function of shaping and gain for the two low-frequency modes of the helicopter. Although the coupling between the various modes is large, the mode furthest to the left, mode 2, is associated with the forward speed of translation. This type of feedback easily gives stability to mode 1 (the pitch mode) for most ranges of the feedback parameters. The parameter k (the position of the feedback zero along the real axis) is equivalent to the ratio of position gain K_P to the rate gain K_R; the feedback gain is the same as K_R. The limiting cases are pure position ($k \to \infty$, and $K_\theta = K_P$) and pure rate ($k = 0$, $K_R = K_\theta$). The optimum value of the ratio term k appears to be near unity ($K_P = K_R$) with a gain K_θ between 0.1 and 0.2. An excessive amount of rate feedback slows up the pitch mode and increases the speed response, and an excessive amount of position feedback quickens the pitch response but makes speed response sluggish.

A slow servomotor (time constant of ½ sec) is included in the open-loop root display of Figure 7. As shown by the figure, the primary effect of the lag term is to rotate the loci originating from the

FIG. 5. Basic automatic-control loop to stabilize helicopter in pitching mode.



pitch mode in a clockwise direction, favoring the loci that are predominate in rate.

Hovering controller

Having stabilized the helicopter in pitch, the next problem is to establish an earth reference over a fixed point. This means eliminating errors due to drift, external disturbances, load changes, etc. A simple mechanization could use a direct earth contact, the ground reference being a small weight connected to a wire cable running through a Scotch-yoke type of guide in the aircraft. The yoke would be actuated via the ground-based cable by both angular and linear displacements of the fuselage. Fuselage pitch and roll may be controlled by subtracting signals proportional to these quantities from the yoke output signals, and resolving the resulting signals into a linear translation error in an attitude resolver for controlling the swash-plate servo. Note that the swash plate controls both attitude and horizontal translation.

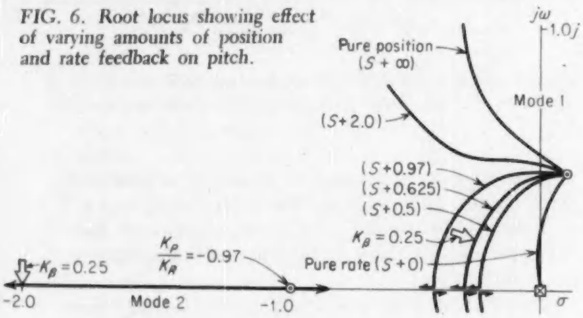


FIG. 6. Root locus showing effect of varying amounts of position and rate feedback on pitch.

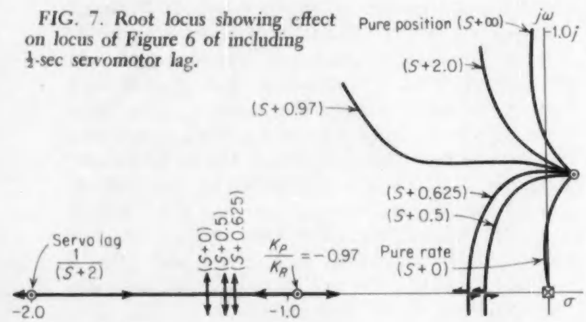


FIG. 7. Root locus showing effect on locus of Figure 6 of including ½-sec servomotor lag.

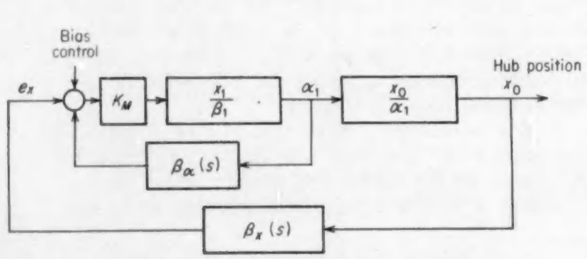
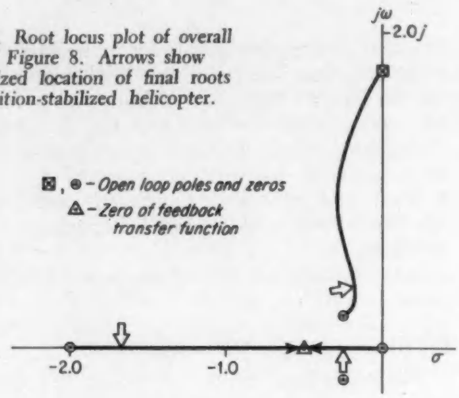


FIG. 8. Complete longitudinal channel of hovering controller for typical helicopter described.

FIG. 9. Root locus plot of overall loop of Figure 8. Arrows show synthesized location of final roots for position-stabilized helicopter.



Altitude may be maintained by holding constant the length of the wire cable unwrapped from a take-up drum. A pickoff mounted on the drum may be used to measure altitude error and provide signals to control a collective pitch servo. The following discussion of control of the longitudinal translation mode could apply just as well to the lateral translation mode. It is desired to determine the feedback gains, lead networks, and general mechanization for performing hovering control. The mechanization is started by making the first-loop closure about the pitch control; this is done, as before, by feeding back pitch displacement and rate, selecting $\frac{5}{8}$ as the ratio for K_P/K_R. The feedback is predominantly rate to counteract any servo lag. Once the helicopter is stabilized in attitude, a fore and aft position control loop can be added. The arrows in Figure 6 show the final poles of the inner loop. The oscillatory pitch mode is stable with a time to damp to one-half amplitude of 2.8 sec and a period of 31.4 sec.

In the synthesis of the outer loop, it is necessary to have the transfer function of $x_0(s)/\alpha_1(s)$:

$$\frac{x_0\,(s)}{\alpha_1\,(s)} = \frac{1.31\,(\text{ft/deg})\,(1/s)\,(s + 0.017 \pm j\,1.77)}{6.96\,(s - 0.0011)} \qquad (18)$$

Since the longitudinal displacement is the outer loop, the stabilized pitch loop is now a "block" in this outer loop, along with the necessary shaping function $\beta_x(s)$. Figure 8 shows an overall mechanization.

A root locus plot of the outer loop having a shaping function of the form $K_X\ (s + 0.5)^2$ is presented in Figure 10. A shaping function of this form indicates that acceleration as well as rate and position information is desirable for the x mode. It is possible that a self-contained system (without earth contact) could be used; e.g., an integrating accelerometer with an extremely low threshold. The arrows in Figure 9 point to the final location of the roots of the stabilized helicopter plus the position-controlling loop.

REFERENCES

1. *HELICOPTER THEORY*, T. H. von Karman, "Zeitschrift fur Flugtechnik und Motorluftschiffahrt", Vol. 12, 1921. Translated in "Aircraft Engineering", September 1940.
2. *HELICOPTER ANALYSIS*, A. A. Nikolsky, Wiley, 1951.
3. *AERODYNAMIC STABILITY AND AUTOMATIC CONTROL*, William Bolley, "Journal of the Aeronautical Sciences", Vol. 18, September 1951.

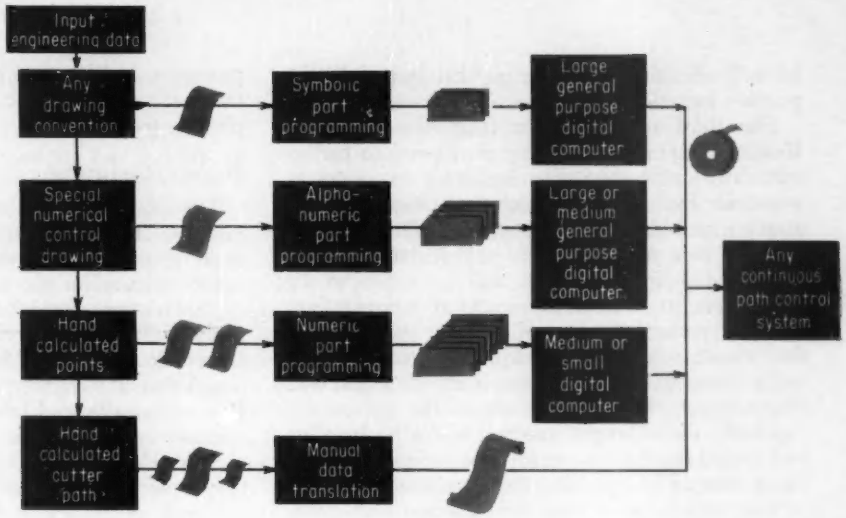


FIG. 1. Block diagram depicts four different approaches to the conversion of engineering data for a part into command information for a numerical path-control system. Methods range from manual computation to the use of large, general-purpose digital computers.

Team Approach to Computer Programs for Numerical Control

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When starting the development of a computer program for numerical control, the people involved decide on basic philosophies. They will choose some key item that serves to establish the paramount aims in the writing of the program.

Some will decide in favor of the computer. This is a particularly likely choice when a small computer of limited capacity is to be used. The small computer is capable of producing an output compatible with the input needs of a machine tool. Because of limited storage capacity, however, it will call for a more precise, detailed input than would be required by the larger computer. For example, in some existing programs for small computers, the part planner must specify which subroutine is to be brought into play. And he often must write down symbols, redundancies, and duplication in order to augment the computer's memory.

Since the computer will accept only a rigid and quite limited set of input conditions, drawing points may have to be found and inserted by the planner. In some programs, only lines and circles are acceptable, and where there are tangencies, the tangent point must be listed.

The advantage of the "small-computer approach" is that the computer program is simple and economical to construct. The main disadvantage is that the program has little relationship to actual drafting practice. Thus the planner must carry a share of the computer's burden. He becomes somewhat of a robot, who must talk in the strange language of the computer.

Another basic approach is to decide that the machine tool is the most important element. Then, the design of the program is started at the computer output, which is tailored to fit the machine tool. Working back, the program designer adapts the computer for translating decimal coordinates to machine tool language. In addition, the computer will probably be used to generate the offsets for the cutter path, and perhaps even to break circles up into straight lines or parabolas, depending on the interpolation system employed.

Here, the disadvantages are similar to those encountered in the first case. The approach is inflexible and places a heavy detail burden on the planner, who will think in terms of programming a machine tool rather than a part. Then, too, the entire program is directed toward the single goal of a particular machine tool system. It is almost impossible for such a program to be modified to feed data to another machine tool system. On the credit side of the ledger, there are the advantages of ease of programming and low cost. An intangible benefit stems from the proprietary nature of the design, which may permanently "win" a customer for the machine-tool builder once the initial sale is made. Once a user has accepted a given system,

he will tend to standardize on that system to the possible exclusion of others.

The third approach is mathematics orientated. Here the job of programming is assigned to mathematicians and computer coders by a management who feels that a numerical control program is just another problem for a computer. The result is likely to be a mathematically perfect, but complex, model. Considerable effort will be expended by the coders to achieve efficiency of computation. And the mathematicians will probably worry a good deal about elaborate geometrical concepts that are quite impractical or uncommon in shop practice. For example, they may include in the system the capability for solving a number of textbook solids and their intersections, or for computing for cutter shapes that no tool grinding shop could manufacture.

The trouble here is that the mathematician probably does not have a broad background of practical shop experience. Thus, when the mathematician finally hands his programs to the planner the latter may well be faced with the necessity of looking at a forging through the eyes of the mathematician. He can no longer use the words he has used during his years in the shop; he must visualize this forging in terms of the intersections of surfaces, and the drawing in terms of solid geometry or vectors. The retraining needed may pose almost insurmountable difficulties. The mathematician will probably not be asked to put his perfect model to daily use, and won't realize the problems he has generated.

A fourth route is through the drawings of the parts that are scheduled to be machined: programs are developed to solve the geometry problems found on these drawings. In addition to the standard solutions, a number of "specials" can be produced so that the planner can readily write instructions with only the data given on the drawing. This method seems sound, and might be adequate for the plant doing the work. However, the shift to a different drafting system might totally baffle the planner. For example, if the programs are based on a coordinate dimensioning system, then a drawing in the standard "chain" system would have to be redimensioned by hand before the planner could go to work. Although proponents may say, "Modify the drafting system to fit the computer programs," this expedient is often not practical and, furthermore, does not dispose of existing drawings.

A fifth approach classifies the language problem as paramount. Both must be taught; but should the emphasis be on teaching the planner to speak computer language, or on teaching the computer to understand English? The more the programmers lean toward the latter, the tougher the computer programming job and the easier the part planning. The answer should be based on cost considerations. How many hours of coding can be expended economically in order to reduce the planner's labors? How many parts will be planner over the life of the programs, and how complex are these parts? How many planners must be taught and how big is the planner training job?

Basic reasoning

The question might be asked, how could so many different schools of thought develop? Every program seems to start with the same fundamental input and aim for the same goal. Where then do these variations come from?

To find the answers, one must look past technical aspects to the human factors involved. It will be found that a computer program reflects the education, experience, and interests of the dominant personality involved. For example, the "computer" and "machine tool" approaches clearly show that they were sponsored by companies who make and sell such equipment. And, as stated before, the "mathematics" orientation prevails when computer programs are assigned to the data-processing people as an exercise in computation. The "language" concept is paramount when the tool design or tool planning departments are responsible. Thus, the program orientation depends upon management's decision as to who in the company has prime responsibility in the numerical control field.

Universal program

At least one of the five approaches discussed above will suit almost any individual company. However, it would be preferable to aim toward the development of a universal program acceptable to all plants utilizing a computer in manufacturing. Although it poses a complex problem, the design of such a program is feasible.

A universal computer program for numerical control should include at least the following features:

1. It should be flexible enough to permit the use of any drawing. If the drawing is complete enough so that a machinist may read it without scaling for dimensions, the planner should find it adequate for computer input without the need for calculating additional points. This implies that the planner will have the option of using either the coordinates from a zero-zero point, or delta values from any previously defined point.
2. The manuscript (or input to the computer) should be simple, self-explanatory, easy to write, and easy to check. The words should be those which are in common shop usage. Abbreviations should be avoided unless they are already common. There should be an absolute minimum of rules, and whatever rules there are should have no "special cases". The computer should, as far as possible, be able to determine meanings of words and definitions from their context.
3. The program should be insensitive to quadrant; in other words, it should accept any mix-

ture of plus and minus dimensions. The planner should not have to put down duplicate figures; the computer should be able to read forward and backward to find the data it needs. Certain items, such as specific cutter diameters and feed rates, should not have to be listed more than once by the planner. It should not be necessary for the planner to write down symbols that are only for the purpose of signaling the computer into specified action. Thus, for example, the computer should be able to recognize the end of a particular instruction by the context, or at least by nothing more complex than a period or comma.

The design of a program embodying these ideals can be accomplished only by a team. This team should consist of the following skilled personnel:

1. A computer systems man.
2. A computer coder.
3. A part planner (preferably an ex-machinist).
4. An engineer-draftsman, familiar with the drawing system to be used by the planner.
5. A mathematician.
6. An equipment man, familiar with the numerical control tools and systems to be used.

Each of these men should be an expert in his field. He should be thoroughly familiar with the company and with his responsibilities to his specialty, or to his organization. It is most important to select the men from comparable levels of authority and position, to avoid authorative pressure interfering with a technical or common-sense decision.

The team's first task is to come to a clear mutual understanding of what the problem is. There are a number of factors in this determination. First, the output desired from the computer is relatively fixed. This is true despite the fact that each machine control system may require a slightly different language, for such differences are readily resolved by translation. Not that writing a translator program is simple; in fact, it may well be one of the most complex parts of the total program. Perhaps it would be best to let the translator (or output, or post processor) take care of all items peculiar to the machine tool system involved. With this approach, the later addition of other kinds of machine tools to a particular plant will require only the writing of a new translator program. The computational pieces of the program will not be affected.

The second major task for the team is to examine in detail the parts to be made and the type of drawings in use, to determine what forms of geometry need be solved, and how the engineering department normally describes this geometry. It is important to compare the information presented on drawings with the information required by the machine tool. This is the gap that the team is to fill. After

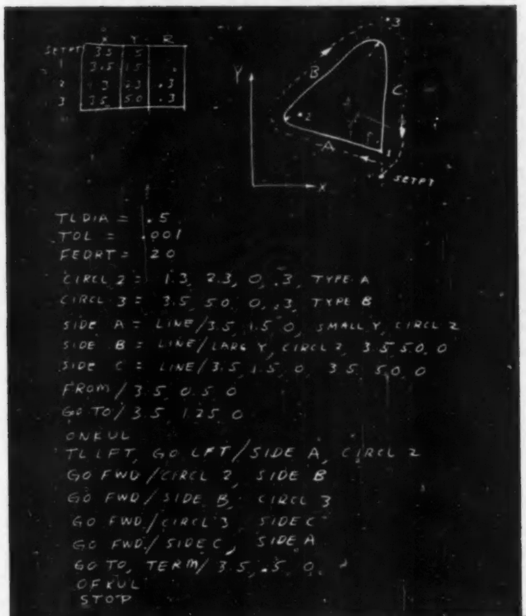
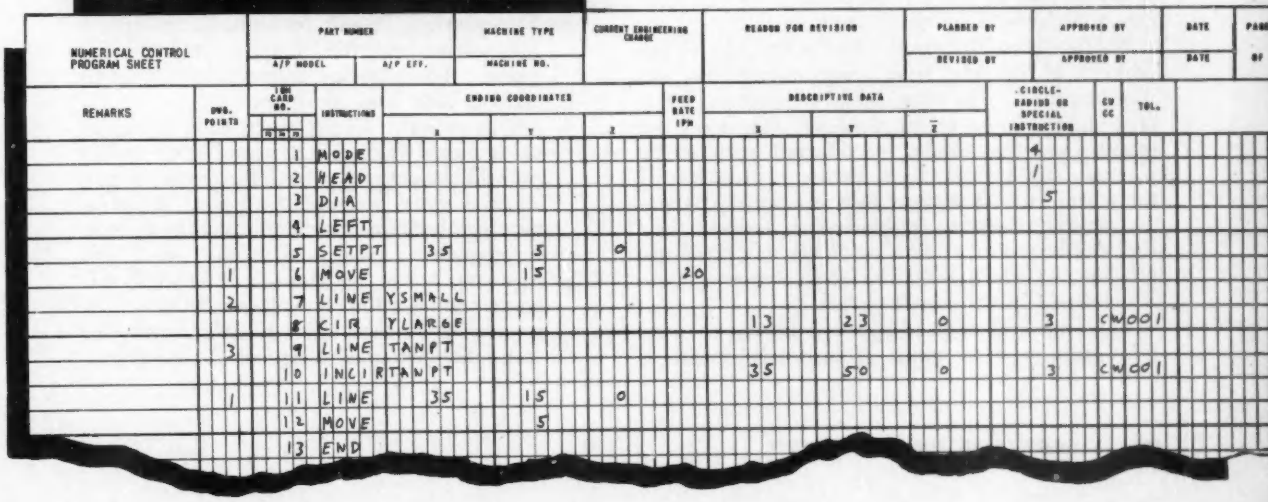


FIG. 3. Boeing manuscript for workpiece shown in earlier illustration.

FIG. 2. Sample ot program sheet for sample workpiece. This is typical of techniques to be available in some programs now under development.



NUMERICAL CONTROL PROGRAM SHEET — PART NUMBER — A/P MODEL — A/P EFF. — MACHINE TYPE — MACHINE NO. — CURRENT ENGINEERING CHANGE — REASON FOR REVISION — PLANNED BY — REVISED BY — APPROVED BY — APPROVED BY — DATE — DATE — PAGE — OF

REMARKS	DWG. POINTS	IBM CARD NO.	INSTRUCTIONS	ENDING COORDINATES X	ENDING COORDINATES Y	ENDING COORDINATES Z	FEED RATE IPM	DESCRIPTIVE DATA X	DESCRIPTIVE DATA Y	DESCRIPTIVE DATA Z	CIRCLE-RADIUS OR SPECIAL INSTRUCTION	CW CC	TOL.
		1	MODE								4		
		2	HEAD								1		
		3	DIA								5		
		4	LEFT										
		5	SETPT	35	5	0							
	1	6	MOVE		15		20						
	2	7	LINE	YSMALL									
		8	CIR	YLARGE				13	23	0	3	CW	001
	3	9	LINE	TANPT									
		10	INCIR	TANPT				35	50	0	3	CW	001
	1	11	LINE	35	15	0							
		12	MOVE		5								
		13	END										

a great many parts and blueprints are analyzed, the team should be able to list the solutions that must be developed to convert available inputs into the required outputs.

A third step is to look carefully at machining practice. This may oblige the team to become quite familiar with the normal sequences of cutting that are selected by journeymen machinists. It is important to know what cutters, both standard and special, are used, as well as what is and is not possible in cutter manufacture, especially in regard to shapes and tolerances. Other areas of study include roughing and finishing cuts, fixturing techniques, warpage, and other variables.

As a fourth step, the team should look at the planning and tool design organizations in the plant. What functions do these departments provide? How close is their liaison with engineering? With the shop? What level of talent and understanding do they maintain? Are they machinists or engineers? What tools (desk calculators, electronic accounting machines, paper reproduction equipment, etc.) do they work with? What will be their responsibility in converting engineering drawings to machine-tool tape? What do they expect or want numerical control to do for them?

Fifth, intelligent program design presupposes familiarity with the numerically controlled machine tools that are expected in the plant. The team must know what motions and auxiliary functions can be performed by these machines, as well as what is required in the way of setup procedures. Again, the team need not be expert, but it should have a good "feel" for the capabilities and requirements of the machine tool.

Last, the team should discuss computers. What computers are available for the work? Which one is best suited to the job? What peripheral equipment is available? Is this enough, or will additional converters be required?

One of the more fundamental decisions concerns the program language. By this time, the team understands the people who will do the part planning and how they talk about a drawing. As a result, the team is almost certain to agree on a language that is normal and natural for the people who will work day after day with the manuscripts.

Another item for consideration is the relative importance of computer time, programming time, and planning time. The team should estimate the hours of computer time to be used per day, week, or month, and the number of different parts to be planned, and evaluate these factors on the basis of the scheduled activation of their computer program. This enables the team to decide how much of their time can be put into obtaining an efficient computer program, or whether a little extra computer time is significant in the overall picture.

This same evaluation will provide answers to questions such as: How much effort can be spent on reducing the planning time? How much desk-calculator time should be eliminated in the planning department? Will it pay to develop a complex routine to solve a relatively rare problem on the engineering drawings? Where should the team members stop, and say, "This program is good enough"? Should they try to solve the general three-dimensional case, or is the simple two-dimensional solution adequate? Should they put effort into having the computer figure feed rates; cutting sequences; rough and finish cuts; pockets; automatic clamp avoidals; corrections for individual machine tool response; and stops for end of tape or for location checking?

There are two other problems about which differences of opinion often arise. One is the format of the planner's manuscript. One school of thought holds that there should be a rigid, accounting-type form, with a place and column for each specific type of information. The other school prefers entering data in a prose or text method, separating dimensions and words by commas or other symbols. The team must decide which best suits their planners.

A second problem concerns the way the cutting instructions are to be given to the computer. Some feel that it is best to define the part to the computer first, and follow this with a list of the sequence of cuts, using symbols for the previously defined points and lines. Others recommend making the part definition and the sequence integral, with the planner describing each point as it is reached in the cutting. Programs have been written both ways, and it seems to be a matter of opinion which is preferable. The team must choose one.

It might be useful at this point to list a few precautions for the team, as follows:

1. Remember that the computer is programmed only once, while parts are planned daily for years. A little extra effort in the computer programs can save time in the planning.
2. The specific words used in the language are of little importance in themselves. The definitions, however, are critical. A word or symbol must always mean the same thing to the planner and the computer. There is no room for ambiguities. Special cases should be avoided.
3. The planners should be required to learn a minimum about the computer and its programs. The planning instructions should be concise, clear, and consistent.
4. Stay practical. Don't waste time trying to cover a case which is rare or unlikely. It will probably be cheaper to have the computer give an error signal occasionally, causing the planner to go back for some hand calculation, than to program for every mathematical possibility.
5. As a corollary to the above, a little additional programming effort is well worthwhile if it is possible by such effort to substantially increase the potential utility of the programs.

Automatic Speed-Torque Plotting

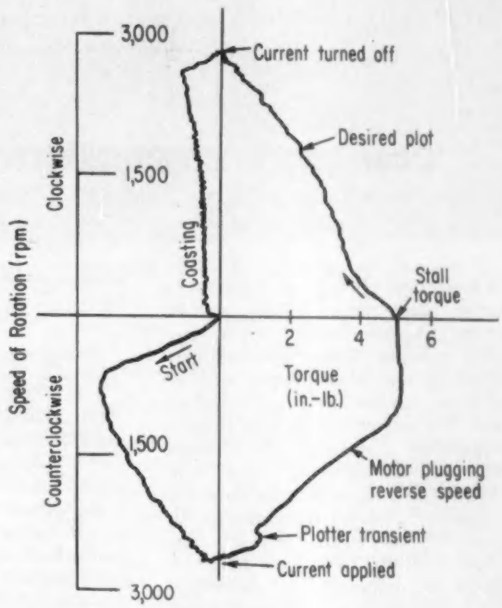
J. O. YEISER and J. P. ANTHONY, Mandrel Industries, Inc.

One way to get a torque-speed plot of an electric motor is to have the motor accelerate a flywheel from zero speed to full speed while recording its speed vs. its acceleration (which is proportional to torque) on an X-Y plotter. Figure 1 shows the usual arrangement: a speed signal from a dc tachometer generator serves as the Y input for the plotter, and the same signal is differentiated for the X input. This method is not too good in practice because dc tachometers generate high-frequency noise that is exaggerated by the differentiating circuit. Filters which can remove this noise will also affect the true acceleration (torque) signal and thus deteriorate the accuracy of the measurement.

The instrumentation shown in Figure 2 avoids this difficulty. Here a dc tachometer generator again delivers a speed voltage to the Y input of the plotter. But an ac drag-cup tachometer generator excited by dc now produces the acceleration signal for the X input. (Any ac tachometer excited by dc produces a dc output proportional to rotational acceleration, but the drag cup type is almost completely noise-free.)

How to use this setup

This test setup can be calibrated by measuring the actual torque produced at a known motor speed. Stall torque is often used because it is easy to measure, but in this case a separate point, such as the no-load speed, is needed to calibrate the speed axis. This latter figure may be derived from the voltage-speed constant of the dc tachometer, or read from a stroboscope, or simply taken from motor nameplate data if precise results are not required.



To get an accurate plot of stall torque, the motor is first given a slow reverse rotation by hand, and then turned on its forward direction so that it accelerates through zero speed. This procedure is necessary because the X-Y plotter cannot respond instantaneously to the voltages produced as the motor goes from zero to stall torque when voltage is suddenly applied to a motor at rest.

Because all accelerations will be faithfully recorded, the desired and the spurious, coupling between the motor and the ac tachometer must be free of backlash. Even loose bearings will add noise to the desired signal. A simple solution that works is to couple the tachometers to the motor with properly tensioned "O" ring belts, using large, high-inertia pulleys to absorb the periodic accelerations due to belt vibration. The flywheel load on the motor must be large enough in any case to permit the X-Y plotter to "keep up" as the motor accelerates.

Figure 3 shows a torque speed plot obtained from the setup of Figure 2. Only that part of the curve in the first quadrant is normally of interest. Friction loading of the motor by brush friction, especially near zero speed, as well as viscous drag in the drag cup generator may have to be accounted for when very small motors are tested by this method.

Fig. 1

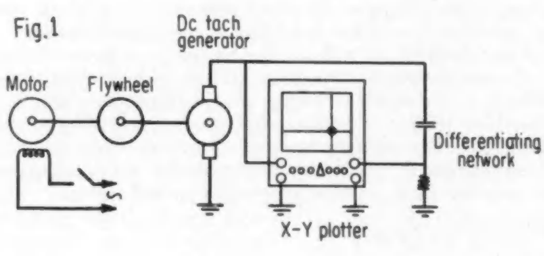
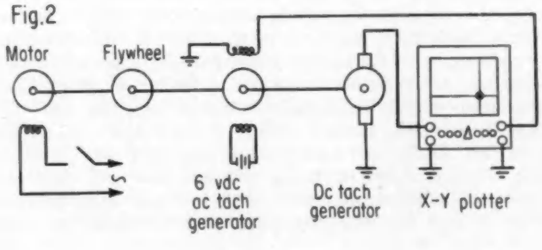


Fig. 2



Are You Installing Electronic Controls?

Successful installation of an electronic control system requires reliable source of power and best method of wiring between field and control room. Author Johnson offers a checklist that aids in determining whether a standby power source is needed and then describes three ways to obtain such reliable power for instruments. Author Carmack describes some wiring considerations for ac and dc signal transmission, shows two different wiring methods, and closes with a table comparing the relative costs of wiring for different types of locations and systems.

CONSIDER EMERGENCY POWER

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Emergency power, on standby in case of plant power failure, may be required for some installations of electronic systems. These systems may control an individual process unit, or they may control integrated refineries where the output of one unit process immediately becomes the charge stream for the following unit. There is not, at the present time, an industry-accepted recommended practice for instrument power supply systems. The checklist in the table may help the instrument engineer to determine whether an emergency power supply will be needed at all; if one is needed, the checklist can be used to find the power supply's characteristics.

The same safety precautions hold for installing instrument power supplies as for the regular plant power system.

On failure of normal plant power, automatic transfer occurs to the emergency supply. Some equipment throws over without any interruption of service or without any noticeable voltage dip. Other equipment may delay by 10, 20, or more sec the return to nominal line voltage and frequency, the permissible delay depending on performance requirements of the process unit and the effects of loss of power or voltage dip on the electronic equipment itself. Prolonged voltage dip or loss of power may create a spurious signal in the control equipment, a correcting signal such as would occur from a process disturbance. Thus the control system may close valves to correct for a disturbance that doesn't exist, upsetting process operation for several hours.

How to get emergency power

▶ Spare feeder—this is the most de-

CHECKLIST FOR STANDBY POWER SUPPLIES

Origin and reliability of plant power sources

If power is purchased: how close is the power company; does plant feeder run underground or overhead; is there a spare feeder and does it have a different route from the main feeder; what is the frequency and duration of power failure or voltage dips; how serious are voltage dips; how does bad weather affect continuity of service; how well manned is the power company's maintenance crew; how accessible are the power lines.

If power is generated: how heavily is the plant system loaded; what are effects of starting up large motors, putting a process back on stream, and voltage dips; are alternate sources of power available for each unit and do they reach the process by the same or different routes; what would be the effects of a fire somewhere between the power house and the process unit and control room; how reliable are controls in the power house; is a standby feeder available from the power company.

Type and size of production unit

Type of unit and its capacity: to what extent do other units or services depend on this unit; do other units perform a similar function and what is their share of capacity; what happens on plant power and instrument power failure; on plant power failure, what functions must be performed by the control system; what effect would a shutdown on one unit have on overall plant operation; do charge streams come from storage tanks or directly from another process unit; how difficult is startup after an emergency shutdown; how would a shutdown of short duration affect product inventory or sales; how critical is unit operation—that is, could any pressures, temperatures, or stream compositions cause a dangerous condition; to what extent are electric alarms and safety interlocks employed as part of the overall system.

Instruments and auxiliary equipment

What is total electrical load for such instrument functions as transmitters, controllers, recorders, valve actuators, alarm annunciators, safety interlocks, instrument lighting, emergency plant lighting, chart drives, and stream analyzers; must components of the same control loop be supplied from the same voltage regulator; what quality must the instrument power have—voltage regulation, frequency, or harmonic content; what effect will instrument power failure have on the control actions of the control system—will valves go full open, full closed, float and gradually approach one position or the other, or lock in place at last operating position; how will these valve actions affect pressures, temperatures, and levels in process equipment; will relays drop out on voltage dip and shut down major rotating or heating equipment.

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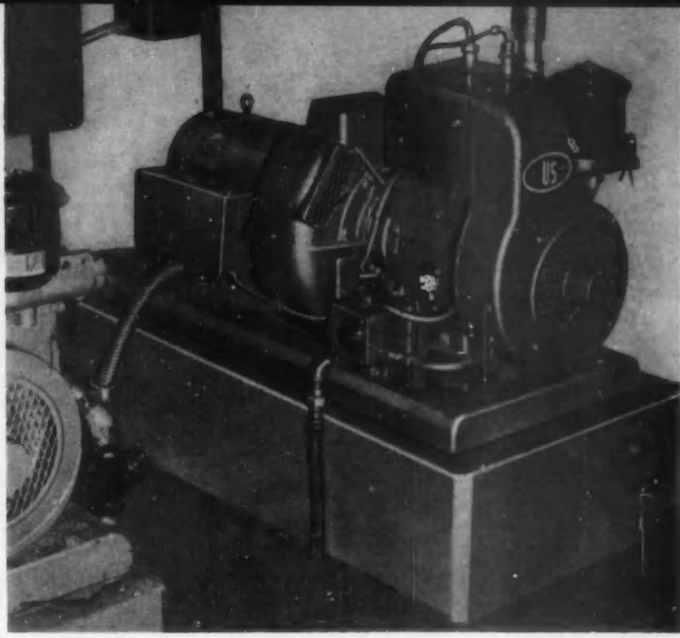
sirable method, if the feeder source meets reliability requirements, since throwover is instantaneous and does not present voltage dip problems. With the exception of transformers and transfer switchgear, there is no major generating or driving equipment to maintain.

▶ Single drive generators—may be driven by such prime movers as steam and gas turbines, and Diesel and gasoline engines. Each driver has features peculiar to itself which—when coupled with process and plant requirements—make it most useful for certain applications. One common disadvantage to this type of emergency equipment is the time delay before the generator comes up to line voltage. The equipment could be kept constantly running to minimize delay, but this is somewhat inefficient. (Though on the other hand, the cost of one unscheduled power failure, no matter how short, might easily cost more than buying and operating a continuously running emergency generator.)

▶ Dual drive generators—may employ an ac motor, a dc motor, and an ac generator, all mounted on the same shaft; or a steam turbine, a dc motor, and an ac generator on one shaft. During normal plant operation the ac motor is the driver, the dc motor charges storage batteries, and the ac generator runs unloaded. On failure of normal plant power, the dc motor is driven by the batteries and the ac generator supplies the instrument load. This type of emergency equipment takes up the instrument load instantly. Its disadvantage is the cost of batteries, dual motors, and attendant maintenance work.


Flywheel-cranked power set generates electricity for emergency powering.

As an example of commercially available standby power systems, United States Motors Corp. (Oshkosh, Wis.) offers 1.5-, 3-, 5-, and 10-kw power sets. The photograph shows an installation of a 3-kw unit. It consists of an electric motor driving an alternator and a flywheel, a magnetic clutch, and an internal combustion engine. During normal operation the motor—connected to the plant power source—drives the alternator to supply power to the instrument load. On plant power failure the magnetic clutch disengages the motor and engages the rotating flywheel to the engine. Cranking at 1,800 rpm, the flywheel starts the engine in a fraction of a second and the engine drives the alternator. Transfer occurs at complete loss of power or at any preset voltage dip between 70 and 90 percent of nominal line voltage.

CONSIDER WIRING PRACTICES

WILLIAM CARMACK, The Fluor Corp., Ltd.

Two important aspects of an electronic control system are its installation and field wiring, for proper attention to these assures optimum performance and minimum maintenance. Only field wiring, that is, wiring between the transmitter and receiver and back to the final control element (valve), will be discussed here. Until the National Electrical Code is revised to cover electronic instruments more fully, all installations should be in accordance with the present code and any local codes.

Low-level ac signals are subject to electrical pickup from external sources and hence require great care in wiring. Protection is by means of metallic shields electrically insulated from the copper signal leads. To be effective, the shield must be grounded, and grounded at one end only to prevent induced voltage and a consequent flow of circulating current in the shield. External insulation around the shield will prevent accidental grounding. Generally, shields are treated as another conductor or lead, with their own terminals at the receiver-controller terminal box. All shields should be connected together and grounded at one point. Preferably, they should terminate in the control room, for then the interconnecting wire can be a short run in the terminal boxes or on the panel and the shields need not be tied together at transmitters and valves scattered about the plant. To avoid accidental grounding at the transmitter or final control element, the shield should be cut back and the exposed end insulated with tape.

Another way of minimizing stray pickup on ac signals is to use twisted pairs of wires, which tend to cancel out any magnetically induced voltages. Multiconductor cables are available that already contain twisted and shielded wire pairs as well as other conductors.

Isolation

Wiring runs for electronic control systems should be completely isolated, both electrically and mechanically, from any other electric circuits in the plant. Electrical isolation means: running a separate ac power line (usually 115 volts from the distribution panel) for the control instruments only; using a separate constant-voltage regulator for the electronic control system only; and running separate grounds, tying them to plant ground through copper leads and not to the wireway, conduit, or panel framing. Mechanical isolation means: using separate wireways (conduit, electrical metallic tubing, duct, etc.) only for the electronic instruments. No attempt should be made to use the same wireway for wires even to such devices

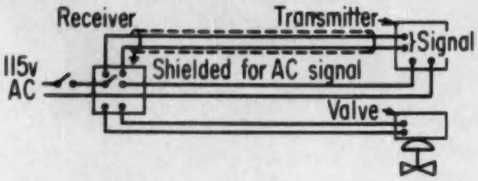
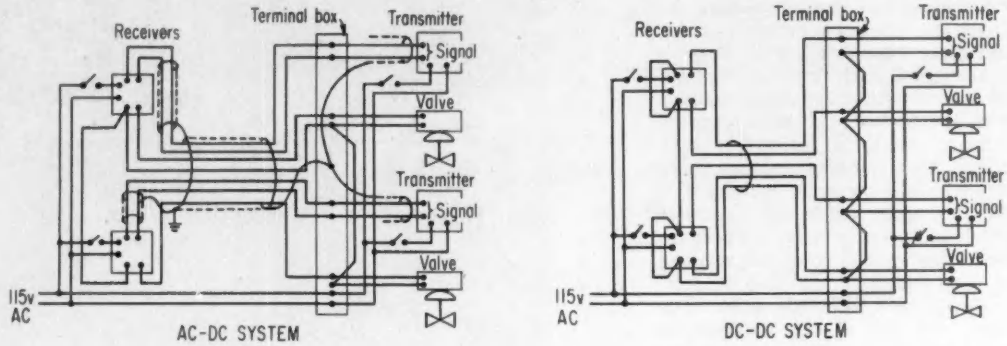


FIG. 1. Field wiring of one electronic control loop.

FIG. 2. Wiring of transmitters and valves located close together.



as solenoid valves, alarms, and the like.

Wiring examples

Signal, power, and control leads may be run in many ways, with gage size determined according to electrical and mechanical requirements or from manufacturer's recommendations. The two ways outlined here represent extremes in possible installations.

Method I: Each loop in the plant is wired separately, so that there will be many loops like that shown in Figure 1. The runs are continuous, with no junctions in leads between control panel and transmitter and valve except for wire-pulling reasons. Ac-transmitter systems require a four-conductor cable (a twisted and shielded pair for the transmitter signal leads and a twisted pair of leads for transmitter excitation), and two single leads from the controller to valve, usually of 14 gage for mechanical strength in pulling through conduit. Similar wiring conditions hold for dc-transmitter systems, but the transmitter leads need not be shielded or twisted. Some valve positioners and actuators need a power source (115 volts ac), and this may be obtained from the control room or from a source in the field.

Transmitter power for ac and sometimes dc systems is from the same source as the receiver-controller. The power-disconnect switch in the receiver-controller may serve both ends of the loop, or a separate switch in or near the receiver-controller may be used for disconnecting transmitter power. Groups of leads for each loop are run individually, but along a common wireway wherever possible. Some leads can be run common to other loops, but to little advantage because of the higher cost of running interconnections between transmitters and valves than using separate wires. All things being equal, it is better from an operating and maintenance standpoint to run separate leads.

Method II is typified in Figure 2, which shows two loops (the method can be easily extended to more). This approach uses standard multiconductor cables to collection points and continuous runs from the terminal box to the transmitter and valve. Cables are multitwisted pairs (6, 11, and 16 pairs are standard and convenient) with a common shield. The transmitted signal and control signal leads for several loops may be run in the same cable if the total number of leads from the terminal box to the control panel is insufficient to warrant using separate cables for each type of signal. For ac signals, the leads in the cable are a shielded, twisted pair. Dc signals use one lead for each valve and transmitter plus a common lead for all transmitters and valves. The common lead must have sufficient copper cross-section to give a low-enough resistance so that signals in one loop do not cause spurious signals in other loops.

Power leads to transmitters (and valves, if required) are run to each terminal box and to individual disconnects near the terminal box for each transmitter and valve. When conduit is used as the wireway, a single conduit containing the multipair cables and a pair of power leads is run to each terminal box.

Method II wiring installations are generally more economical than Method I under the following conditions: long distances (about 200 ft or more) between the control room and the field; where transmitter valve groupings are located close to one another. Method II also offers the designer more flexibility, for locations do not have to be too exact in the early design stages and wireway sizes and number of leads in each cable can be estimated with sufficient accuracy to cover most contingencies.

The table compares typical costs of the two methods for systems using ac transmission and dc control and systems using dc transmission and dc control. Costs include labor and material and are given as relative cost (to the dc-dc system), for labor and material costs vary throughout the country. The cost of wiring methods not covered should fall within the range of the figures shown.

RELATIVE COST OF WIRING INSTALLATIONS

	Small plant—Short run—Scattered locations	*Large plant—Long runs—Close locations*
METHOD I		
ac—dc	*1 percent higher*	*23 percent higher*
dc—dc	*17 percent lower*	*0 percent even*
METHOD II		
ac—dc	*10 percent higher*	*16 percent higher*
dc—dc	*Base*	*Base*

Nonlinear Systems Design

PART II
HOW TO INTERPRET THE PHASE-PLANE PLOT

THE GIST: Part I of this article (CtE, October, p. 69), described several ways to construct phase-plane plots of system performance. The value of such plots depends on how well the user understands the relationships between the shape of the trajectory and the behavior of the system. On the following pages the author explains these relationships and illustrates the interpretation process by means of some typical nonlinear systems.

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Purdue University

Characteristic patterns in phase-plane plots identify modes of system operation. Usually, these patterns surround a *singular point* in the system response, i.e., a point at which derivatives of the system variable are zero. Such a point thus always appears on the horizontal axis of the phase plane and represents a static solution of the system equation.

For example, the linear quadratic system considered in Part I of this series had a damping ratio greater than 0 but less than 1. For that particular case a *stable focus or spiral* represented the solution. For the same system with a damping ratio greater than 1, the trajectories move more directly to the origin without encircling it and the origin is called a *stable node*. With a damping ratio $\xi = 0$, the trajectories form circles or elipses about the origin, which is then called a *vortex* or *center*. When ζ is less than zero, the trajectories spiral away from the origin, which as a result represents an *unstable focus*. The table on the next page illustrates these and several other singularities discussed below. It also shows the locus of roots associated with each.

Interpreting the phase-plane plot of a control system would be considerably simpler if common criteria of system performance, such as damping ratio and number of overshoots in the step function response, were directly available. Still, the systems designer can obtain these quantities for the linear quadratic system and then extend the concepts directly or by analogy to more complex systems. This is exactly what is done in linear systems analysis.

The step function response and the number and size of overshoots may be taken directly from the phase-plane plot. One of the graphical methods discussed in Part I will establish equal time increments along the trajectory. The time response of error or output (whichever is being used on the phase plot) can then be plotted separately or read directly from the time-marked phase plot.

Equation 6, Part I, yields for the damping ratio of a typical linear second-order system:

$$\zeta = \frac{1}{2}\left[\frac{dy}{de} + (1+k)\frac{e}{y}\right] \tag{1}$$

Since error is zero along the vertical axis of the plot,

$$\zeta = -\frac{dy/de}{2} \tag{2}$$

Thus, the system damping ratio may be read directly from the phase plot as minus one-half the slope of the trajectory as it crosses the vertical axis. If real time is used, the slope must be further divided by ω_0, the undamped natural frequency. It would appear that this simple but useful relationship has not previously been pointed out.

TYPICAL SYSTEMS

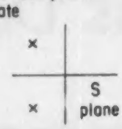
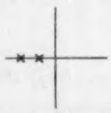
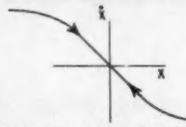
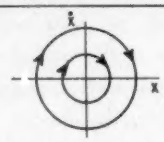
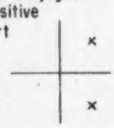
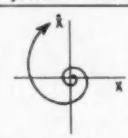
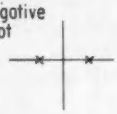
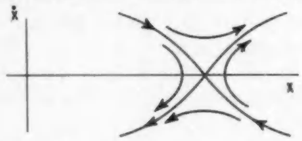
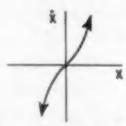
The simple pendulum

Some examples of nonlinear systems will best illustrate some of the other phase-plane characteristics. The system shown in Figure 1 (also discussed by Andronow and Chaikin—Ref.1) represents a damped simple pendulum with a constant driving force or torque. Motion of the system satisfies the equation

$$a\ddot{\phi} + b\dot{\phi} + c\sin\phi = T \tag{3}$$

where a is a torque coefficient due to the accelerating force; *b*, a torque coefficient due to viscous damping; c, a torque coefficient due to the gravity force; and *T*, the applied torque. The equation is of

Six typical singular points

Singularity	Roots	Phase-plane portrait
Stable focus or spiral	Damped complex conjugate 	 Trajectories spiral asymptotically to focus
Stable node	Stable real roots 	 Trajectories approach node monotonically
Vortex or center	Imaginary roots 	 Conservative system or oscillator
Unstable focus	Complex conjugate with positive real part 	 Trajectories spiral away from focus
Saddle point	One positive - one negative real root 	
Unstable node	Two positive real roots 	 Trajectories diverge monotonically from node

general interest, for it also describes the operation of an ac synchronous motor and that of the usual closed-loop automatic phase-control system. In the first case, the variable may be interpreted as the torque angle of the rotor, and in the second case as the system phase error. Figure 2 shows a model of this equation and a block diagram of a typical automatic phase-control system that also satisfies the equation. Points of equilibrium, or singular points, exist where $\dot{\phi}$ and $\ddot{\phi}$ are zero. At these points, the first two terms of Equation 3 drop out and

$$\phi = \sin^{-1}(T/c) \tag{4}$$

Although an infinite number of points satisfy this relation, there are only two such points for any one revolution of ϕ. The first of each pair is a *stable focus*; the second, a *saddle point*. These correspond to the positions of stable and unstable equilibrium shown in Figure 1. Notice that as T increases, both the focus and saddle approach $\pi/2$; and that if T becomes greater than c, all real static equilibrium points vanish. In general, as here, the driving function influences the singular points of a nonlinear system. Figure 3 illustrates phase trajectories of the system for various values of ζ. The focus in this figure may be defined as a singular point representing the common asymptotic point for a family of concentric spirals. The other type of singular point shown is called a *saddle point*. Only asymptotes tend toward a saddle point; the other paths, being hyperbolas, do not pass through the point. The special path or asymptote which does tend to a saddle point has been termed a *separatrix* (Ref. 1).

If the coefficient of damping is adjusted for a given T, such that the trajectory moves from a saddle along the separatrix to the next saddle, the system becomes critically damped. With increased damping the trajectory spirals into the intervening

focus and the system becomes over-damped; with decreased damping, the trajectory gathers velocity and does not return to a stable equilibrium point, but approaches asymptotically a fixed dynamic path called a *limit cycle* (Ref. 1). This represents the path over which the energy dissipated each cycle by the viscous damping equals the energy added each cycle by the applied torque. While a limit cycle may be a closed path surrounding a singularity, it differs from the paths surrounding a center. Trajectories approach a limit cycle for initial conditions either inside or outside it, but with a center they are kept to elliptical or circular paths around the center, each path being determined by the initial conditions.

Backlash

One rather common nonlinearity in control systems is *deadband*. This is a region in which a given input signal produces no output. Overlapped hydraulic valves and electric relays are components that have deadband. Gears and linkages exhibit a special kind of deadband called *backlash*. Backlash differs from deadband in that it depends on the past history of the input and not simply on its present value. As usual, the particular location of a nonlinearity in a loop definitely influences the type of response. Truxal (Ref. 2) gives as an example a positioning system with backlash in the output gear train and load inertia concentrated first on the motor side of the gear train and then on the output side. The case of backlash beyond the motor, and no appreciable load inertia, is perhaps even more interesting, since it leads to the possibility of oscillation and a limit cycle in the phase plane.

Figure 4 shows a simple positioning system in which the amplifier has been assumed perfect. The time constant and integration refer to the motor armature. Transfer to error is

$$\frac{e}{R} = \frac{1}{1+A} = \frac{(1+Ts)s}{(1+Ts)s+K} = \frac{(1+Ts)s}{Ts^2+s+K} \qquad (5)$$

Assume that for zero input the initial conditions place the system at point A, Figure 5. The system follows the spiral trajectory to point *B*, where motion of the motor armature changes direction and the loop opens because of the backlash in the gears. The system then operates as a simple quadratic with a constant input of minus *B*. Time t_b, required for the system to traverse the given dead zone, is easily calculated. At the end of the dead zone, output again assumes the velocity of the motor (geared up or down) and follows the spiral trajectory on which it finds itself at the time (point *C*). No acceleration problems exist since load inertia has been assumed negligible. At point *D*, the gear train again disengages and t_b sec later (at point *E*) the gears again engage and the system proceeds as before.

Notice that point E may be either inside or outside of the original trajectory, depending on the shape of the spirals. If the system is heavily damped, or if the interval t_b is very short, the transit from *D* to *E* will appear on a spiral inside the original path and the response will converge toward the origin. But if the system is lightly damped and/or has a relatively long time interval, the response could expand out to a stable limit cycle. These limit cycles reveal a great deal about the general response of a system, and considerable effort has been devoted to establishing criteria for their existence.

If the system in the example above tends to be unstable, it would probably approach a limit cycle rather than oscillate at continuously larger amplitudes, because of the viscous damping. Of course, in an actual system, the limit cycle oscillation might

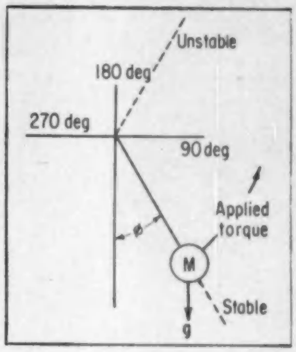


FIG. 1.
Damped pendulum with constant applied torque.

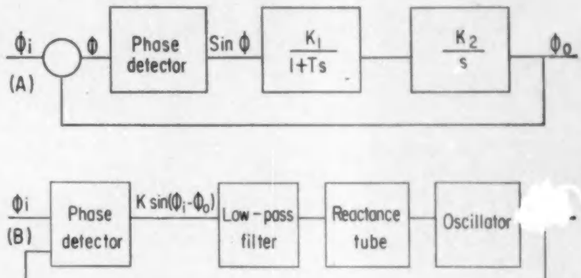


FIG. 2. ***A—Model of Equation 3; B—block diagram of an automatic phase-control system.***

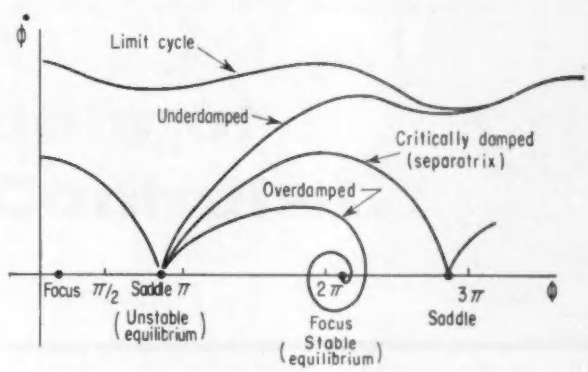


FIG. 3. ***System phase trajectories for several different damping ratios.***

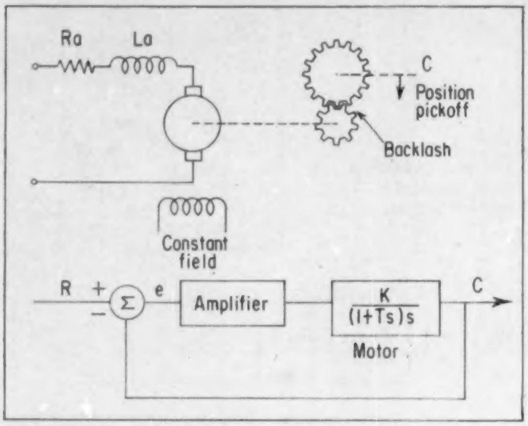


FIG. 4. Sketch and block diagram of a simple positioning system with backlash.

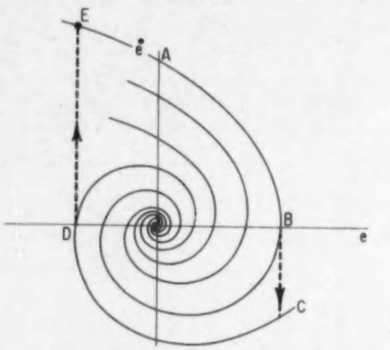


FIG. 5. Phase-plane plot of a system with backlash.

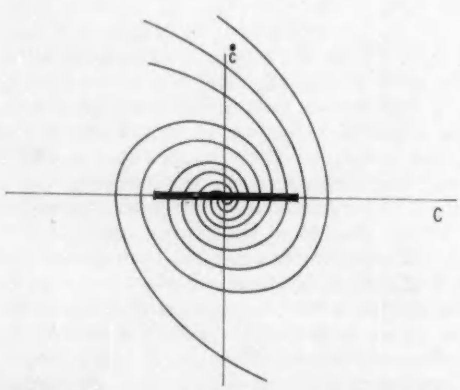


FIG. 6. Phase-plane plot showing coulomb friction line.

be destructive in amplitude. In most systems it would be undesirable at any amplitude.

Since backlash varies with the rate of change of output*, it is somewhat more difficult to handle than deadband, which is fixed with respect to position. The phase-plane plot of the latter can be handled like that of the piecewise linear system discussed in Part I.

Coulomb friction

Another rather common type of nonlinearity exists in systems where, in addition to the usual viscous damping, there is some coulomb or static friction on the output shaft for instance. This coulomb friction exerts a constant retarding force at the output shaft, independent of velocity. It is objectionable in systems having no integration, since large final errors can exist, and in systems with an integration, since it may produce oscillations. Figure 6 shows the locus of coulomb friction superimposed on the spirals of an otherwise linear system. The trajectories are no longer skewed spirals that can be converted to orthogonal spirals by a change in variable. Instead, they have undergone a nonlinear warping.

With the system initially at some point in the phase plane, the solution point will trace along a trajectory until it meets the locus of coulomb friction. At this point motion ceases, since here the coulomb force is greater than the driving force. If the system contains an integration not affected by coulomb friction, an error signal will build up and the system will break free. It can be shown that under these conditions a limit cycle may result. In the final part of this series, several nonlinear systems, including the system with backlash, will be considered in detail to see how performance might be improved.

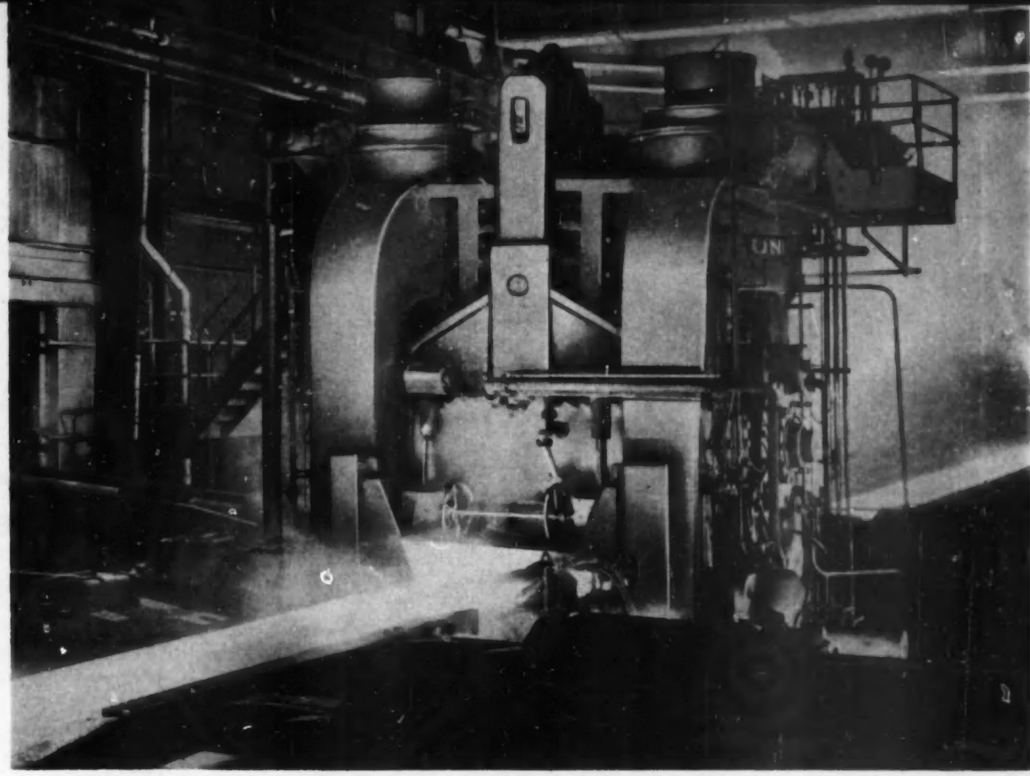
Note that throughout these examples the system response depends on both the type of input and the relative location of the nonlinearity. The present state of the nonlinear servo art might very well be likened to the period around the turn of the century, before operational and vector methods were introduced into electric circuit analysis and each problem required a separate solution of a differential equation. Part III of this series on nonlinear systems design will introduce some of the problems of system synthesis on the phase plane.

* This is only true for continuous motion, such as limit cycle oscillation or a transient after it has been initiated.

REFERENCES

1. *THEORY OF OSCILLATIONS*, A. A. Andronow and C. E. Chaikin, Princeton University Press, Princeton, New Jersey, 1949.

2. *CONTROL SYSTEM SYNTHESIS*, J. G. Truxal, McGraw-Hill Book Co., Inc., New York, 1955.



Reversing roughing stand with tie-motor control of movements of horizontal and edger rolls and side guides.

Fundamentals of Tie-Motor Control—I

Users of synchro-tie systems have now logged enough experience to put their design on a scientific, rather than cut-and-try, basis. The key to successful operation of such systems is a "firm-enough tie"—and in this first of two articles, the author explains how to select and connect motors to provide a rigid coupling for different combinations of load characteristics.

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A synchro tie is a means for reproducing motion or transmitting torque without mechanical connection between the input and output units of the system. Each system includes a transmitter (input) and a receiver (output), which actually are identical wound-rotor induction motors. The secondary windings of these tie motors are connected together, while the primaries are excited from a common source of electrical power. Now, if the shaft of either tie motor is turned, the shaft of the other will duplicate that motion, provided the torque limits of the motors are not exceeded.

The performance ("follow-up" ability) of a synchro-tie system depends on the firmness of the tie between transmitter and receiver. The degree of firmness achieved in any system design is determined by the electrical connections and by how closely the tie motors are matched to the application. The choice of tie motors is somewhat more complicated than normal motor selection because horsepower, torque and duty-cycle ratings are not the only cri-

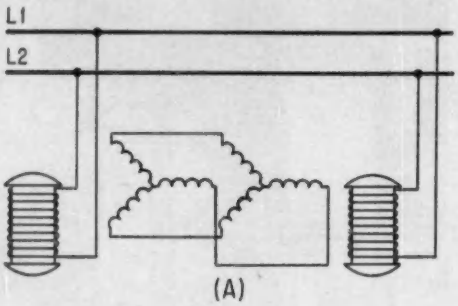


FIG. 1. Schematic circuits for synchro ties using single-phase motors with salient poles (A) and distributed windings (B).

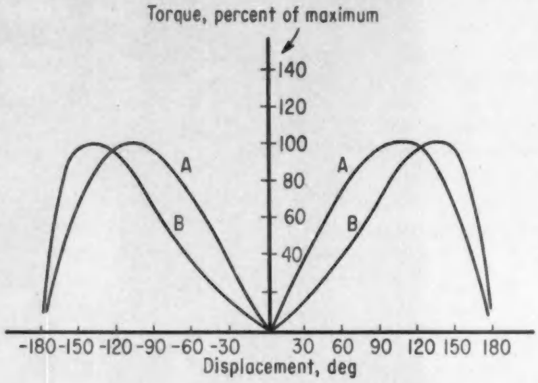


FIG. 2. Torque-displacement characteristics for single-phase tie motors. Curves A relate to salient poles and curves B to distributed windings.

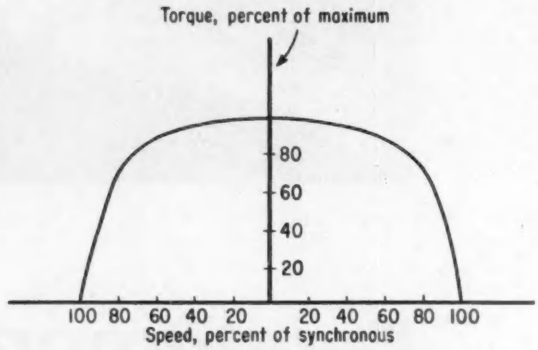


FIG. 3. Speed-torque relationship for typical single-phase synchro tie.

teria. The construction of the motors, as well as the way they are excited and connected, also affect system performance and must be tailored to suit the load characteristics.

The many uses of synchro-tie systems can be grouped into four broad classifications that are distinguished by the nature of the load, as follows:

1–Light loads at slow speeds
2–Power loads at slow speeds
3–Light and power loads at high speeds
4–Special drives requiring high stability

Slow speed is defined as any speed below two-thirds the synchronous speed of the tie motors involved. Any speed above this is considered high; top speed is limited only by the induced rotor voltage and the mechanical strength of the units.

Light loads–slow speed

Light loads and slow rotational speeds are characteristic of uses such as remote indicating, signaling, and recording. In this type of application, the receiver load usually consists of a slowly moving pointer. The tie motor best suited for such service has a single-phase, two-pole primary of either the salient-pole or distributed-windings type, Figure 1. These two-pole units have three-phase secondary windings and lock in step in one position only. Figure 2 shows the torque-displacement curves for both salient-pole and distributed windings. It can be seen that the salient-pole winding produces a greater torque than the distributed winding for the same angular displacement. At standstill, the torque developed by the receiver is equal to the torque acting on the transmitter shaft, minus the electrical and mechanical losses.

For remote indication, where the total travel is usually less than one revolution of the transmitter rotor, the performance of the tie system is relatively unaffected by interruptions in the excitation supply; that is, the units will reset accurately each time that excitation is reapplied. This characteristic makes for simple control. It is necessary only to provide a switching means for opening and closing the primary circuit. To arrange for reversal of the direction of rotation of the receiver with respect to that of the

transmitter, the control designer may use some form of double-pole, double-throw contacts for interchanging any two interconnecting secondary leads.

When tie-motors operate under continuously running conditions, some means must be provided for resetting after power failure. Should power be cut off, the motors may easily get out of step by more than one revolution. And while such a tie-motor system will react to any phase difference of less than 360 mechanical deg (for two-pole motors), it cannot discriminate between whole revolutions. The reason for this is, of course, ambiguity; a null point occurs within every 360 deg of rotation. One approach that the control engineer could undertake to prevent ambiguity is to parallel the tie-motor system with a second loop containing two geared-down synchros and some type of null indicator. The synchro loop will null only once in a great number of revolutions of the tie motors and, thus, can be used to determine when the system is more than 360 deg out of step. Regardless of what synchronizing means is adopted, it is advisable to recommend that the tie motor system be energized before the transmitter is rotated. Further, the loop should not be de-energized until rotation has stopped.

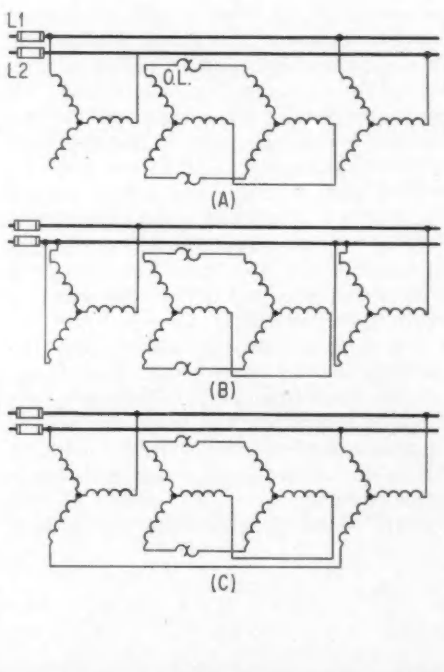
Figure 3 shows the characteristic curve of the retarding torque of the receiver (or the torque delivered by the transmitter) vs. speed for typical single-phase tie motors. It can be seen that under running conditions, the torque speed curves are symmetrical for both directions of rotation; and that torque decreases with an increase of speed, becoming zero at synchronous speed. In single-phase applications, it is advisable to select tie motors having a synchronous speed at least 50 percent above the maximum operating speed expected. This measure is necessary in order to obtain sufficient tie torque. The three-phase connecting leads between the transmitter and receiver secondaries should be of as low resistance as possible. High-resistance leads tend to reduce the available torque.

In the case of driven load with high inertia, there may be a tendency for the receiver to overshoot when excitation is applied. Under such conditions, the receiver will oscillate or, possibly, run as an induction motor. This fault can usually be overcome by applying a damper to the single-phase receiving unit.

Power loads—slow speed

The second application classification involves the coupling of loads that deliver or receive appreciable power, but operate at low speeds. The conditions are in many respects similar to the class of applications described above. The principal difference here is that machines of greater capacity are required. A satisfactory and economical unit for this use is a standard wound-rotor, polyphase induction motor with either two-phase or three-phase stator windings. These windings are connected for single-phase excitation to provide symmetrical torque-displacement and torque-speed characteristics. The tie motor connection need not be changed in reversing service.

Because the maximum receiver torque available in systems having single-phase excitation is much less than that for polyphase excitation, the rate of acceleration and load peaks must be studied carefully. Despite this drawback, the single-phase arrange-



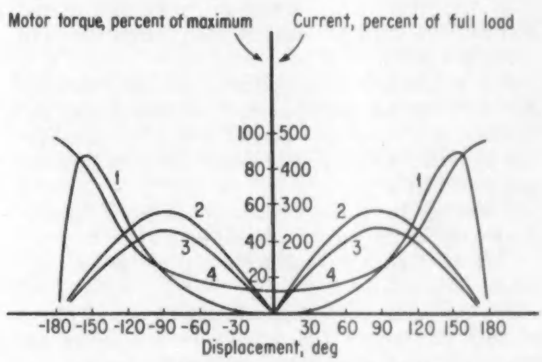
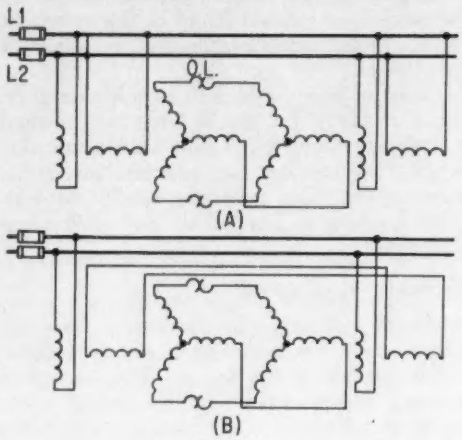


FIG. 5. Torque-displacement characteristics for single-phase operation of polyphase primary. 1—one phase open; 2—two phases in parallel; and 3—common connection. Curve 4 shows primary current vs. displacement.

FIG. 4. Three methods of connecting a three-phase primary for operation on single phase. A—one phase open; B—two phases in parallel; C—one common connection.

FIG. 6. Two methods for connecting two-phase primary for single-phase operation include primary phases in parallel (A) and second phases bucking (B).



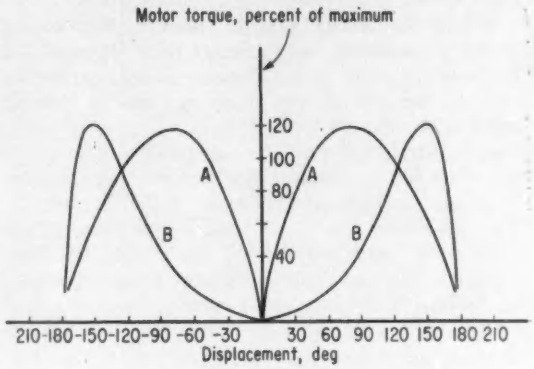


FIG. 7. Torque-displacement curves for tie motors connected as shown in Fig. 6.

ment is common because installation and control are simpler than for polyphase excitation. Here again, the tie motors selected should have a synchronous speed at least 50 percent greater than the maximum operating speed expected for the application.

As shown in Figure 4, there are several methods of applying single-phase excitation to three-phase tie motors. These are as follows:

1–Apply the single-phase excitation voltage across two stator terminals, with the third terminal open.

2–Connect two stator terminals together and apply the excitation voltage between these common terminals and the third terminal.

3–Apply the voltage across any two terminals and connect the third terminal of both transmitter and receiver together.

For continuous single-phase operation, the last two schemes are preferred to the first because the torques developed are greater for small displacements. The torque-displacement relationships are given in Figure 5.

There are three single-phase connections feasible for two-phase tie motors also. These are:

1–Both phases in parallel across single phase excitation (Figure 6).

2–One phase energized, while the second phase of both transmitter and receiver are connected together for additive induced voltages to cause a circulating rotor current.

3–A connection similar to 2, except with the induced voltages bucking so that there is no circulating rotor current in the second phases.

The torque-displacement curves for these connections are given in Figure 7. The first arrangement is advised for most applications because it yields much greater maximum torque values and provides a firmer tie.

Two-phase tie motors with single-phase excitation have performed very satisfactorily in an automatic screwdown control for rolling mills. As shown in the schematic diagram, Figure 8, an adjustable potentiometer driven by the screwdown provides a signal voltage to indicate the position of the rolls. The two synchro-tie motors function as an electrical coupling to permit remote mounting of the potentiometer unit in the pulpit or control room. The transmitter is geared to the screwdown drive and the receiver to the potentiometer unit.

Polyphase primaries—polyphase excitation

When excited from polyphase power, polyphase tie motors exhibit operating characteristics that are considerably different than either single-phase tie motors or polyphase tie motors with single-phase excitation. For example, the torque-displacement curves for single-phase units and for polyphase units with single-phase excitation are symmetrical, but the torque curves for polyphase excitation are not. This difference is due primarily to the fact that motors with polyphase excitation have a revolving magnetic field that generates two torque components. The first is a synchronizing component that is caused by rotor displacement and acts to decrease the displacement angle. The second component is produced by rotor losses and acts in the direction of the revolving magnetic field.

When it is working with the field rotation, the receiver actually delivers more torque than is impressed on the transmitter shaft. Conversely, the delivered torque is markedly less when the receiver is turning against field rotation. These conditions are evident in the torque-displacement and speed-torque curves of Figure 9.

If the rotors of the tie motors are not in their

synchronous position when power is applied to the primary windings, the tie motors will accelerate toward the synchronous or zero-angle position. The energy stored in each rotor during this period is a function of the average torque and the displacement angle through which the rotor moves to reach the zero position. When the torque-displacement angle characteristics are symmetrical (as for single-phase excitation), the rotors will oscillate about the zero position until friction brings them to rest.

In the case of polyphase excitation, however, the torque-displacement angle characteristics are unsymmetrical. Therefore, the energy stored in one of the rotors as it moves toward the zero angle position may exceed the amount of energy that the rotor can dissipate in less than 180 electrical deg movement beyond the zero angle position. In such cases, the rotor will slip a pole and motoring action will result. If both the transmitter and receiver are free to rotate, they will accelerate until they come into synchronism and then coast toward standstill. Near standstill, they may or may not pull out of step and accelerate again.

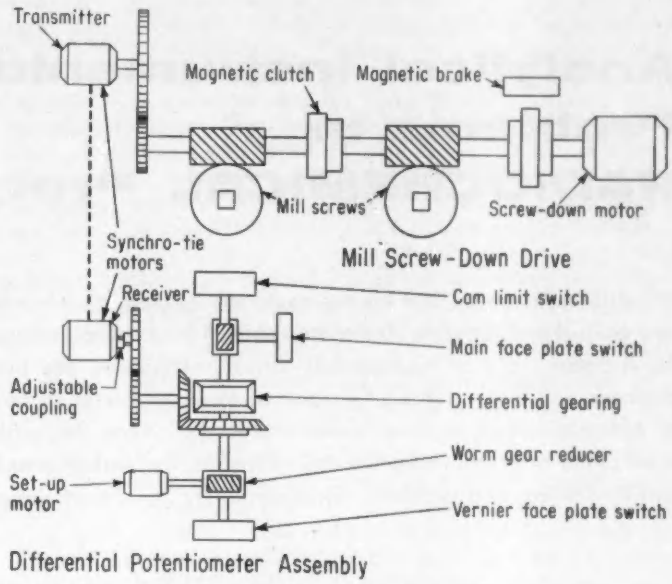


FIG. 8. Schematic of synchro tie for steel mill screwdown control.

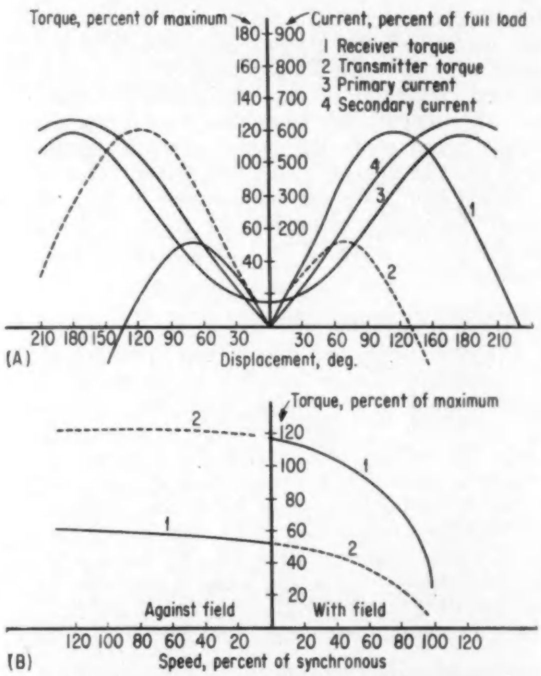
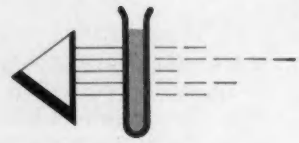


FIG. 9. A—Performance characteristics for three-phase tie motors with three-phase excitation. B—Speed-torque curves for same type of motor.

To eliminate this form of unstability, it was always advisable to apply only single-phase excitation at first to both the transmitter and receiver. After they had pulled into step, the tie motors could be given full excitation. This procedure was sometimes performed in three steps. In the first step, single-phase power was applied across two terminals with the third terminal open, to provide a high synchronizing torque at large displacement. Next, the third terminals of transmitter and receiver are tied together to yield substantial synchronizing torque but at less displacement. This action holds the transmitter and receiver firmly in step. The third step consists of connecting all three phases to the line. Although this procedure greatly reduces the inherent disadvantages of polyphase excitation, it does not serve when the units are displaced by exactly 180 electrical deg. At this displacement and with single phase excitation, torque is zero and the tie motors will not synchronize.

The second part of this article, which will appear in the February issue of CONTROL ENGINEERING, will complete the discussion of the control of tie motors with polyphase excitation. In addition, the special requirements of high-speed loads and of applications in which stability is critical will be considered.



Analytical Instrumentation Problems in RADIOCHEMICAL Processes

THE GIST: Processes that involve radioactivity pose an interesting array of new control problems. With the approach of economical nuclear power and the increased use of radioisotope tracer techniques, the process control engineer will find solutions to many of these problems in the application of automatic analytical instruments (Ref. 1). Here the author discusses some of the principal radiochemical processes, the variables to be measured and controlled, and problems encountered by instrument designers.

ROBERT C. AXTMANN, E. I. du Pont de Nemours & Co., Inc.

Process streams carrying radioactive materials fall into three classes, depending upon whether the presence of radioactivity is 1) *unavoidable*, as in the case of a nuclear fuel reprocessing plant, 2) *accidental*, as it might be in the cooling effluent from a nuclear reactor, or 3) *by design*, as in processes to which radioactive tracers have been added.

Unavoidable radioactivity

Unavoidable radioactive processes occur in nuclear fuel reprocessing plants and plants that purify uranium ore. Other examples can be found in the specialized processes for recovering specific isotopes from the bulk wastes of atomic energy operations. Purification of the fission product Sr^{90}, a radionuclide sometimes used in "atomic" batteries, falls in this latter category.

The purpose of any nuclear fuel reprocessing plant is to recover unused fuel for reuse. In heterogeneous nuclear reactors, the fuel elements form separate pieces and may be processed in plants some distance away from the reactor. In homogeneous reactors, the fuel is in the form of a dissolved salt or slurry that circulates through the reactor. The reprocessing plant for a homogeneous reactor may be a part of the circulation loop. In this case, separation of undesirable by-products (e.g., fission products from the uranium fuel or gases from the circulating fluid) is essentially instantaneous.

Most radiochemical processing today (alternative processes are in the development stage—Ref. 2) is done by solvent extraction. In this process, the uranium or uranium alloy is dissolved in acid, then the resultant aqueous solution of uranyl salt is contacted with an organic solvent, such as hexone or tributyl phosphate. Here the process takes advantage of the different degrees of solubility of the uranyl salt and fission product salts. With properly adjusted conditions of flow, temperature, acidity, and salt strength, the uranium will pass into the organic phase while the fission products remain behind in the aqueous phase, which then becomes a waste stream. Later the uranium may be stripped out of the organic phase into an aqueous stream and the process repeated until the uranium is sufficiently pure.

Accidental radioactivity

Accidental radioactive streams may occur whereever radiochemicals are handled or processed. A typical example is the cooling water effluent from a power reactor. If a heat exchanger were to spring a leak, the cooling water side might become contaminated, making it necessary to shut down the process before public lands or waters were polluted with hazardous radioactivity. The rupture of a fuel element within the reactor (signified by fission product radioactivity) might also make it necessary to shut down the reactor. Either case clearly indicates a need for warning or shutdown mechanisms.

Intentional radioactivity

A decade ago, processes which contained radioactivity by design would have been hard to find.

Increased availability of radioactive isotopes and a growing knowledge of their usefulness have led to widespread application of tracer techniques in a relatively short time (Refs. 3, 4). In these applications, minute amounts of tracer are added in forms that are compatible with, but not harmful to, the process. In the petroleum industry, for example, where perhaps the greatest use has been made of tracer techniques, the napthenates of Sb^{124} and Co^{60} are added to hydrocarbon streams. Measurements to which tracer techniques have been applied successfully include:

- Completeness of mixing of both solids and liquids
- Liquid carry-over rates in separation processes, such as centrifugation
- Entrainment of various kinds, e.g., organic in aqueous, aqueous in organic, or liquid in gaseous phases
- Leakage rates of valves, heat exchangers, etc.
- Flow patterns
- Flow rates
- Stack loss rates
- Packing fractions

In some cases a temporary use of tracers serves to determine certain plant conditions, such as initial flow patterns. In others, those wherein the operator must promptly detect a minute failure or leak (e.g., a heat exchanger with hydrogen fluoride on one side), the tracers become a part of the process.

Composition of the stream that bears radioactivity may be determined either by sampling and analyzing in a laboratory or by use of in-line analyzers. As more of these in-line instruments become available, greater use will be made of tracer techniques.

VARIABLES TO BE MEASURED

A variable of prime importance in any process involving radioactive materials is the radioactivity itself. A nuclear fuel reprocessing plant separates unused fuel from highly radioactive by-products. A measure of the radioactivity at any point in the process indicates progress to that point.

Of the three most common forms of radiation, alpha, beta, and gamma, the last is usually the most convenient. Gamma rays are more penetrating than either of the other two forms, and so offer fewer restrictions in instrument design. Also, gamma ray detectors available today are extremely sensitive. The most common use sodium iodide crystals (activated by thallium), which respond to gamma rays by scintillating. Photo-multiplier tubes convert the scintillations to electrical pulses, which are then amplified and counted with conventional scaling or count-rate circuitry. Occasionally, other instruments such as Geiger tubes or ionization chambers are used to detect gamma as well as alpha or beta radiation, but these lack, by several orders of magnitude, the sensitivity of the scintillation detector. The combination of gamma-active tracers and scintillation detectors affords maximum utility from tracers with minimum hazard.

Another variable of almost universal importance to radiochemical processes (with the exception of tracer processes) is the concentration of heavy metal salts such as uranium, thorium, and plutonium nitrates. These concentrations span three different ranges, each of which may require a different type of instrument. High concentrations (about 1-500 gm/liter) occur in the main process streams of fuel processing plants. Waste streams usually contain only 1 percent or less of the amount in the main streams; higher concentrations here would probably indicate misoperation and potential economic loss. The lowest concentrations occur in waste effluent streams that are discharged to rivers, lakes, and seepage basins. Here almost any concentration may be pertinent from a public health standpoint.

Table I summarizes the concentration ranges of interest and methods that might be used for detecting uranium nitrate at a single nuclear fuel reprocessing site.

Another variable frequently critical in any radiochemical separation process based on solvent extraction is the acidity of the aqueous phase. Acid is used as a salting agent in many of these processes

TABLE I
DETECTION METHODS FOR URANYL NITRATE

Salt concentration	Location	Detection method
1–500 gm/liter	Process main streams	Density, colorimetry, x-ray, or gamma absorptometry
10^{-3} to 10^{-1} gm/liter	Process waste streams	Colorimetry (with added reagent), alpha or gamma counting, polarography
10^{-4} to 10^{-7} gm/liter	Waste water effluents	Alpha or gamma counting

TABLE II
RELATIVE DEPOSITION OF RADIOACTIVITY

Material	Gamma activity after 600 hours*
Lucite	0.28
Fluorothene	0.54
Tantalum	0.61
Inconel	0.70
Polystyrene	0.74
Teflon	1.0
Titanium	1.42
Gold	1.42
Polyethylene	1.70
347 stainless steel	2.7
Boltaron	5.9

*Normalized to 1.0 for Teflon

and its concentration determines the distribution of the radionuclide between the two phases. While acidity, in principle, is a fairly straightforward measurement, the stringent requirements of maintenance, reliability, and radiation resistance normally rule out the use of conventional instruments.

These three measurements, radioactivity, heavy metal salt concentration, and acidity, probably account for at least 90 percent of the desirable analyses in a nuclear fuel reprocessing plant.

DESIGN PROBLEMS

Many of the problems of designing analytical instruments for radiochemical processes are not very different from those found with other in-line analyzers. The presence of radioactivity, however, compounds the usual difficulties and in some cases introduces new problems.

Sampling

Volumes in the instrument cell and tubing must be kept as small as practicable to minimize radiation exposure of maintenance personnel. Particularly in fuel reprocessing plants, merely obtaining the sample may present a difficult problem in applied engineering. The salt solutions are often quite dense—a typical stream containing uranyl nitrate and nitric acid may have a specific gravity as high as 1.7. This makes the sample stream difficult to handle. In addition, the solute may tend to precipitate in the small sampler tubing. Because of the high radiation fields close to the process, the sampler tubing may extend as far as 100 ft. Leaks of any kind, in tubing or instrument, could spread contamination.

Standardization and calibration

To a production man, a most convincing type of calibration is that in which the stream to the instrument is replaced by a sample that has been carefully analyzed in a laboratory. Such a calibration becomes extremely difficult, however, when the instrument is located behind 5 ft of concrete, as might be the case in nuclear fuel reprocessing. Sometimes an electrical analog calibration may be substituted; the greatest problem then would be to convince the production man that the analog is a valid one. Often the solution is an internal source of radiation which can be blanked off when not in use.

Construction materials

Many common materials deteriorate quite rapidly in the high radiation fields that exist at the start of nuclear fuel reprocessing cycles. Ordinary glass, for example, darkens quickly in high gamma ray fields, and this must be taken into account in the design of optical instruments such as colorimeters. Fortunately, radiation-resistant glass is available. Certain other materials that may have excellent properties as gaskets or electrical insulators lose their superior qualities rapidly and irreversibly in strong radiation fields. Most electronic components hold up well, but transistors and other semiconductors become less reliable under such conditions.

Deposition of radioactivity

The designer of instruments for monitoring radioactivity in flowing streams usually finds most troublesome the tendency of radioactive species to coat surfaces with which the stream comes in contact. This deposition produces a variable background signal which confuses and, in some cases, completely masks the signal arising from the stream itself. The weight of material deposited is negligible (about 10^{-10} gm/cm^2) and in most cases is much less than would be contained in a monomolecular film.

The precise mechanism of this deposition is often obscure. The rate and total amount vary not only with composition of the stream and surface, but also with surface conditions. In the case of some metal alloys, the deposition may simply be a case of isotope exchange, wherein the radioactive species substitutes for a nonradioactive isotope. In the case of metal surfaces, electrodeposition appears to be the most likely mechanism. Where plastics are concerned, neither isotope exchange nor electrodeposition is possible; some sort of adsorption may be taking place. With the submicro quantities involved, however, chemical combination probably cannot be completely ruled out.

FIG. 1. Cross-section of the "Swirl Cell" monitor shows how centrifugal action prevents deposition.

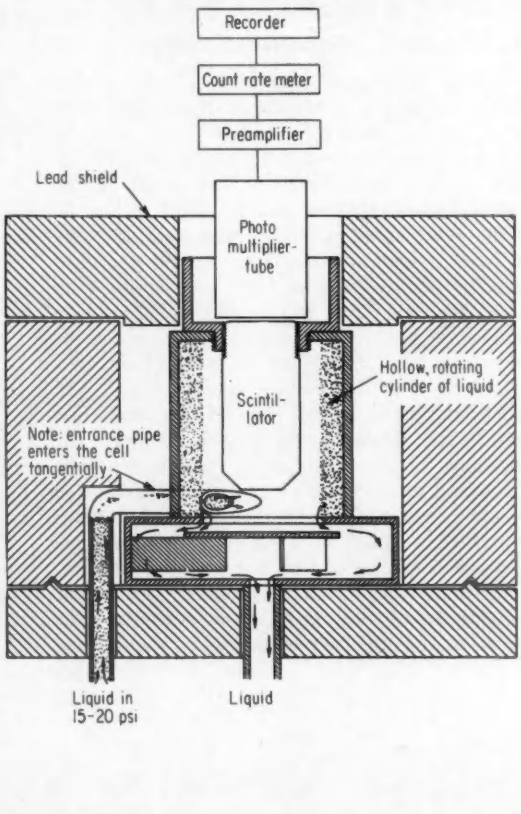


Table II gives the results of an experiment performed at Oak Ridge National Laboratory. These figures are based on work performed by Dr. Kelly, Dr. Stelzner, and J. W. Landry, and emphasize the care that must be exercised in choosing materials for in-line analyzers. Coupons of various "inert" substances were immersed for 600 hours in a nitric acid solution containing tracer amounts of gamma and beta active isotopes, notably Cs^{137}, Ru^{106}, Zr^{95}, and Nb^{95}. The solution was an actual waste stream from a fuel reprocessing plant. The second column in Table II gives the relative gamma activity that was deposited on the coupons during the test. No attempt was made to clean the surface after the tests. It would seem that a gamma monitor with a Lucite sample cell would give a signal-to-background ratio almost 10 times better than one made from 347 stainless steel, provided that other background signals are negligible.

A number of additional factors complicate the deposition problem even further: 1) the deposition is frequently a nonlinear function of time and may require an excessive time to reach equilibrium; 2) every radioactive process stream seems to behave differently, i.e., a material which is suitable for monitor construction in a plutonium-bearing stream may be completely unsuitable in a uranium stream.

One way to avoid the entire deposition problem is to design the monitor so that no liquid comes in contact with the detector. Figure 1 shows a cross-section of the sensing head used on one such monitor, the "Swirl Cell". The detector is a plastic cylinder that scintillates when bombarded by beta or gamma rays. Process solution (at 15 psig) enters at the bottom tangentially to the cylindrical cell wall. At a flow of about 2 gpm, centrifugal force maintains a cylindrical column of water completely separated from the scintillator. The water drains out through baffles to an outlet at the bottom. By paying careful attention to the design of the inlet and outlet orifices, it is possible (Ref. 5) to produce a splash-proof cell. The scintillator plastic is coupled optically to a photomultiplier tube that connects to the amplifying, count-rate, and recorder circuitry shown in block diagram form in Figure 1.

Maintenance

A final problem is that of designing the instruments for fast, simple maintenance under adverse conditions. In fuel reprocessing plants, for example, a maintenance mechanic may have to wear so much protective clothing that he is actually unable to make any fine adjustments. The best solution is to build the instrument with a reasonable number of plug-in units that are cheap and rugged and can be repaired at leisure in a radiation-free location provided they have not been badly contaminated.

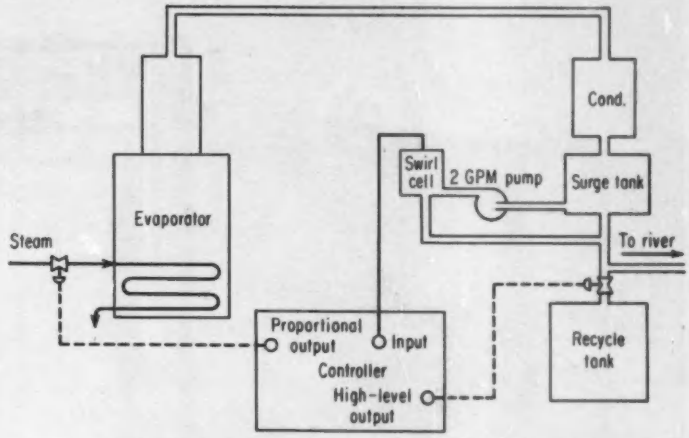


FIG. 2. Typical closed-loop control system for a radiochemical evaporator.

APPLICATION

The flow diagram in Figure 2 illustrates the application of analytical instrumentation to a typical radiochemical operation, the reduction of radioactive waste volumes by evaporation. Condensate from the evaporator collects in a small surge tank and is pumped through a Swirl Cell that measures the level of radioactivity. Normally the condensate will be faintly radioactive, not enough to prohibit its discharge to a river. Should the radioactivity approach an unsafe level, a signal from the Swirl Cell to a proportional controller acts to throttle the steam supply to the evaporator. Conversely, if the radioactivity falls below the "safe" level, more steam is supplied and throughput increases. If the radioactivity suddenly increases to a very high level, due, for example, to a bump-over in the evaporator, the controller will shut off the steam and divert the condensate from its normal discharge path to a catch tank where it will be held for reprocessing.

REFERENCES

1. ANALYSIS INSTRUMENTATION, H. R. Karp, "Control Engineering", May 1957, pp. 95-101.
2. FUEL REPROCESSING BY LOW-DECONTAMINATION AND VOLATILITY METHODS, E. L. Anderson, "Nucleonics", December 1957, pp. 44-49.
3. USING TRACERS IN REFINERY CONTROL, D. E. Hull, "Nucleonics", April 1955, pp. 18-21.
4. FOLLOWING LARGE-SCALE PROCESSES, V. P. Guinn, "Nucleonics", May 1956, pp. 68-72.
5. A BETA-GAMMA MONITOR FOR LIQUID STREAMS, E. C. Wingfield, "AEC Research and Development Report DP-177", September 1956.

Acknowledgement

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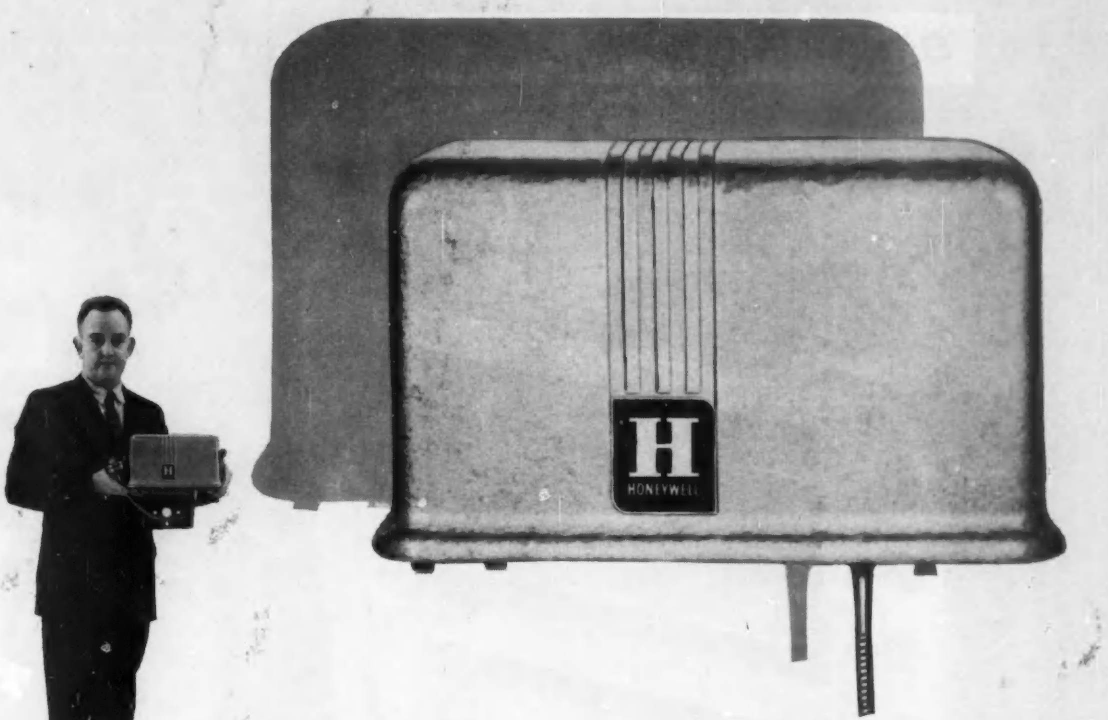
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Oven for computing resistors and capacitors receives up to twelve drawers of components. Engineer points to regulated outer oven that pre-heats connecting wires to temperature of precisely-stabilized inner chamber.

WHAT ANALOG COMPUTER USERS SHOULD KNOW ABOUT STATIC ACCURACY

How to Evaluate Static Accuracy

Static summing accuracy, being the foundation on which over-all computing precision rests, deserves careful analysis by computer users. A single figure like ".01% accuracy" has little meaning unless supplemented by less ambiguous statements. Fortunately, static error caused by modern high-gain, low-drift amplifiers is negligible; therefore, questions of static accuracy can be answered by discovering how well input and feedback resistors have been matched in order to produce resistance ratios of 1:1, 10:1, etc. The following questions are pertinent.

(1) Exactly *how* are resistors matched? Each with every other? Or each with a few others in a group?

(2) What is the matching error upon installation?

(3) How will environmental conditions such as temperature affect accuracy?

(4) Will accuracy deteriorate with age and use? If so, how much?

(5) Will resistors added to expand capacity at a later date match those initially installed?

Let us examine these questions in greater detail.

Two Methods of Matching Resistors

One method is to match resistors in groups of four or five—each to be used only in conjunction with one or more of the others, as input and feedback resistances for a certain amplifier. This method can provide sufficient accuracy, but computer capacity is unnecessarily limited because input resistors cannot be freely transferred from one amplifier to another as needed.

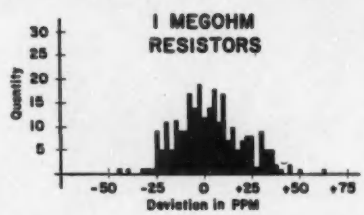
An alternative is to match each resistor with every other in the computer, so that every element will be available for use wherever needed. The EASE computer people have accomplished this by calibrating all computing resistors against a single master standard carefully maintained under laboratory conditions.

The master standard is a group of 100K resistors specially-selected to deviate from a central value less than ±2 PPM and guaranteed to differ no more than ±15 PPM from an absolute 100K value. 1M computing resistors are calibrated against the ten 100K resistors connected in series. 100K resistors are calibrated against the *average* of the ten 100K standards so that the 10:1 ratio is free from the possible 2 PPM deviation of the standards. 200K and 500K computing resistors are similarly calibrated against group averages to achieve exact 5:1 and 2:1 ratios respectively. Using these calibration practices, all computing resistors in an EASE 1100 Series computer are initially adjusted to *within 10 PPM* of the ideal value.

Effect of Temperature On Static Accuracy

No static accuracy figure is meaningful unless accompanied by a statement of the environmental temperature range over which specified accuracy can be achieved. Because EASE computing resistors are installed in an oven maintained within ±0.5° C of a constant temperature, resistance changes due to temperature are less than 15 PPM—this despite external temperature variation from 65° F to 110° F and line voltage changes from 105 to 130 volts.

Field tests have confirmed the effectiveness of this mode of calibration and temperature control. Figure 1 shows the distribution of 100K and 1M resistors in an operating computer. A fact worthy of emphasis is that measurements were made *at the patchboard* under actual operating conditions; consequently, all possible sources of error have been taken into account. With precision computing equipment, only tests made under operating conditions are dependable because so many unpredictable factors such as slight connector contact resistance, wiring resistance and possible human errors in calibration can influence the theoretical result. Note that *typical resistance deviation is about ± 20 PPM* and maximum deviation is 50 PPM except for 1 delinquent out of 1000 which has strayed to 60 PPM.



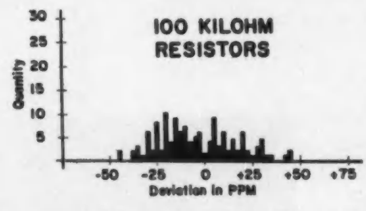


Figure 1. Distribution of all 100K and 1M resistors in 1100 Series computer used at EASE Los Angeles Computing Facility. All measurements made at the patchboard under actual operating conditions.

Aging Effects

The principal effect of age on resistors is to modify resistance values as heat stresses set up in manufacturing processes slowly decay. To forestall this effect EASE computing resistors are heat-cycled four times far above and far below operating temperature in order to remove heat stresses before calibration.

Although no EASE 1100 Series computing resistors have been in service long enough to make a definitive report an stability over a period of years, preliminary tests indicate very low drift. A group of computing resistors, kept at the EASE laboratory for long-term testing, show no greater individual deviation outside the original calibration tolerances than ±15 PPM over a period of six months.

Will Later Expansion Affect Accuracy?

An analog computer user must give due weight to the possibility that an initial installation may require expansion at a later date as new problems are encountered and new solution techniques developed. At that time it becomes important to obtain new resistors matching those originally installed. Here also the use of a single master standard for calibration is advantageous. Provided the master standard has not drifted in value, new risistors can be calibrated to match those in the computer as well as the initial set.

Absolute drift of a few parts per million is difficult to detect with certainty, but all evidence indicates that the EASE standard has not drifted. None of ten basic resistance standards show detectable long-term drift over one year when compared with each other or when compared to other high-stability standards within the laboratory. Since it is extremely improbable that these standards have all drifted the same amount and in the same direction, we infer that the absolute value is holding steady.

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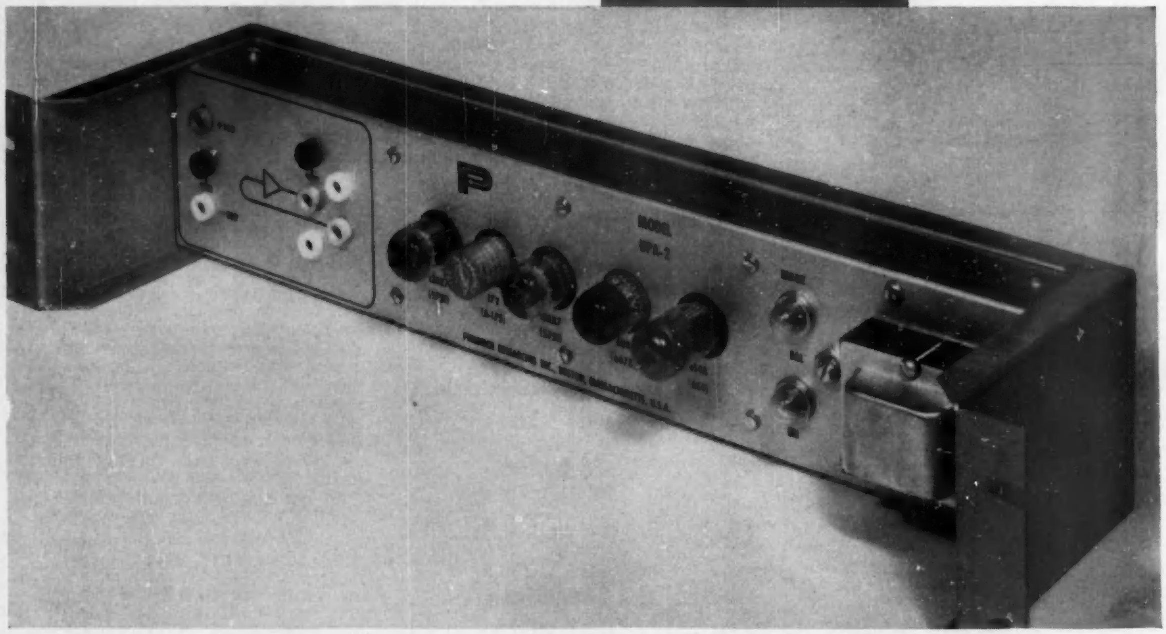

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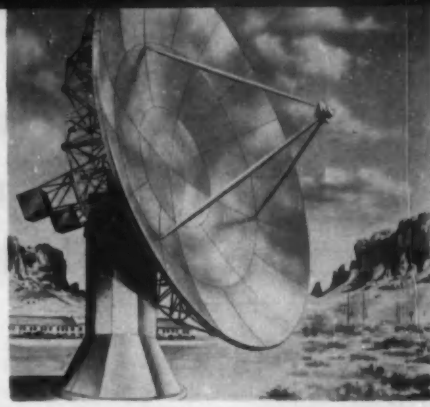


FIG. 1. Sixty-foot reflectors and AZEL mount controlled by eddy current clutch servo system.

Eddy Currents Position Mammoth Tracking Antennas

MARTIN KANNER and ART FEIN, General Bronze Corp.

Mammoth antennas, 60 to 90 ft in diameter, are required for effective tracking of space vehicles or stars. Such antennas, when designed with full azimuth and elevation scanning abilities under severe operating and environmental conditions, may have a dead load of 100,000 lb.

In Figure 1, the design of an integral tracking system for a remote area, the servo controls may be located in the base of the closed-in tower with other electronic equipment.

Besides high accuracy, rapid tracking, and reliability, these controls must assure smooth tracking at all speeds and also provide a high slewing speed. The speed difference between tracking and slewing is so great that the most economic solution in the past has been to combine a low-power servomotor with a separate high-power slew motor. This, of course, means complicated gearing and clutching arrangements.

One way out of all problems—speed as well as gearing—is via the eddy current clutch. This clutch transmits power to the load by interaction of the field of an electromagnetic yoke on the shaft of a motor driving at constant speed, and the field due to eddy currents induced in a metal disc mounted on the load shaft.

With the eddy current clutch:

- Power transmission is smooth from lowest to slew speeds
- There are no commutators or slip rings, so higher reliability and rf-noise-free operation is obtained
- The drive motor is continually turning at full speed. Thus, high accelerations may be achieved with a motor smaller than normal by utilizing the inertia of the motor
- The servo is independent of the motor characteristics and is dependent only on the clutch transfer function, which can be made very good

If the inductance of the eddy current clutch field can be made negligible, then its overall transfer function can be reduced to the form

$$\frac{\theta_L(s)}{E_{in}(s)} = \frac{K_e}{s(\tau s + 1)}$$

In the clutch now in use, τ has been reduced to 0.1 sec. A tracker using this clutch has been built for the National Bureau of Standards' 60-ft parabolic antenna, which must be positioned to an accuracy of 2 min of arc while tracking at 0.1 rpm in winds up to 30 mph.

Figure 2 is a system block diagram for the NBS tracker. The transmission is a two-speed (fine-coarse synchro system, giving a high-accuracy data transmission system. The amplified signal is fed to a pair of eddy current clutches in a push-pull arrangement. Tachometer feedback maintains stability.

This system also contains a speed programmer which can: set the antenna to any desired position; drive the antenna at any desired velocity; or rapidly slew the antenna system into position for missile tracking. Speed programming is done by driving the synchro transmitter by means of an instrument rate servo. The speed of the servo is determined by an accurately calibrated reference voltage. The position servo driving the antenna system is then used to track the output of the rate servo.

Tracking and speed programming could have been done by feeding rate information directly to the receiver and using the receiver in a rate mode. But the separate rate servo makes the accuracy in tracking insensitive to varying wind loads and component gain changes. Also, although the effective gear ratio changes in the elevation axis, special nonlinear pots are not needed.

Work on breadboards of the eddy current clutch system (Figure 3) indicates that reliable accuracies as high as 1 min of arc can be realized under operating conditions should the future demand more precision.

FIG. 2. Eddy current clutch servo is a position servo that can follow a rate servo signal from the speed programmer inputs.

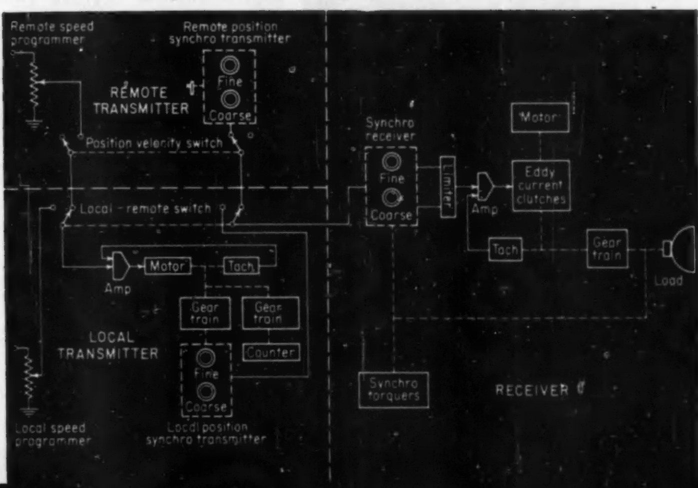
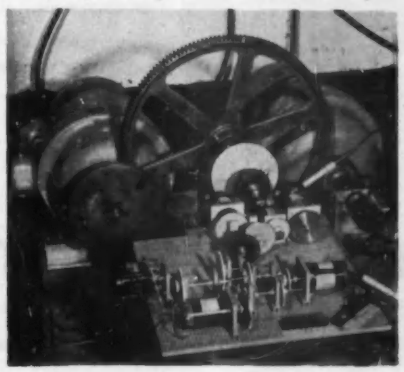


FIG. 3. Breadboard for eddy current clutch servo. Note push-pull arrangement of clutches to load gear.



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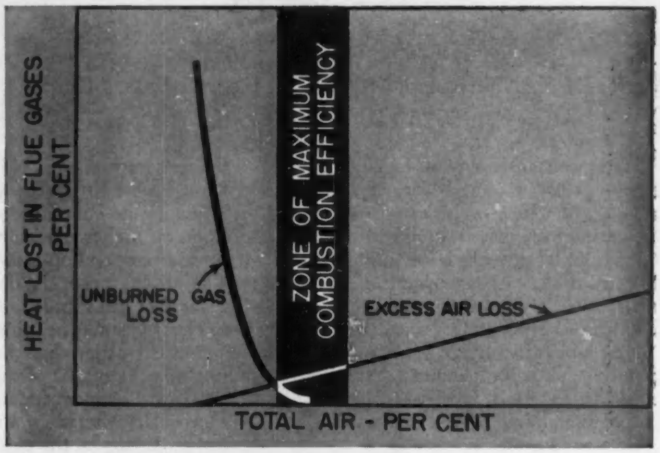

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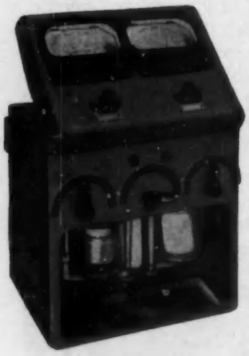
For portable use— HEAT PROVER Analyzer



The famous Cities Service HEAT PROVER analyzer is now Bailey built and sold. Weighing only 25 pounds, it is a self-contained automatic analyzer including a sampling tip and hose plus a thermocouple for temperature measurement.

Instrument dials are dual range for greater accuracy and sensitivity.

For permanent installation Oxygen-Combustibles Recorder

The Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart. These records enable the operator to keep fuel burning equipment performing continuously in the zone of maximum combustion efficiency. Excess air may be reduced to the point where combustibles begin to show.

G 40-1

Instruments and controls for power and process

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

LOGIC Tests Precision Instrumentation Tapes

The great amounts of data now being crowded onto magnetic tapes for computers and instrumentation are raising quality requirements of these tapes to precisions not required so far in any other industry. There are several contributing factors:

- higher and higher recording densities (up to 2,000 bits per linear inch of tape are not unusual)
- multiple tracks (although a small defect, such as a lump or a hole in the oxide coating, may be unimportant when a tape is recorded across its whole width, it can cause complete loss of a recorded bit if it passes under the center of a very narrow recording track)
- demands for greater recording accuracies

Audio Devices, Inc., has developed and is using a tape-testing machine that records up to 42 million pulses on a 2500-ft reel of tape, checks each pulse for playback, and rejects any tape having a single failure.

The tape transport on the machine is a commercially available unit and is operated at 60 in. per second. The recording current is obtained from a standard pulse generator. The pulse repetition rate is set to produce 100 to 200 magnetic pulses per inch of tape, depending on specifications. If the maximum of seven tracks of simultaneous recording is used on a ½-in. tape, a 200-per-inch repetition rate will put 1,400 pulses on each inch. The pulse duration is set to give a suitable signal for the amplifier circuits.

Interchangeable reproducing head plates allow different reproducing head configurations to be put on the machine, the particular configuration depending on the width of the tape and the number of tracks for which it is intended. The electronic equipment allows from one to eight reproducing heads to be used simultaneously (see diagram).

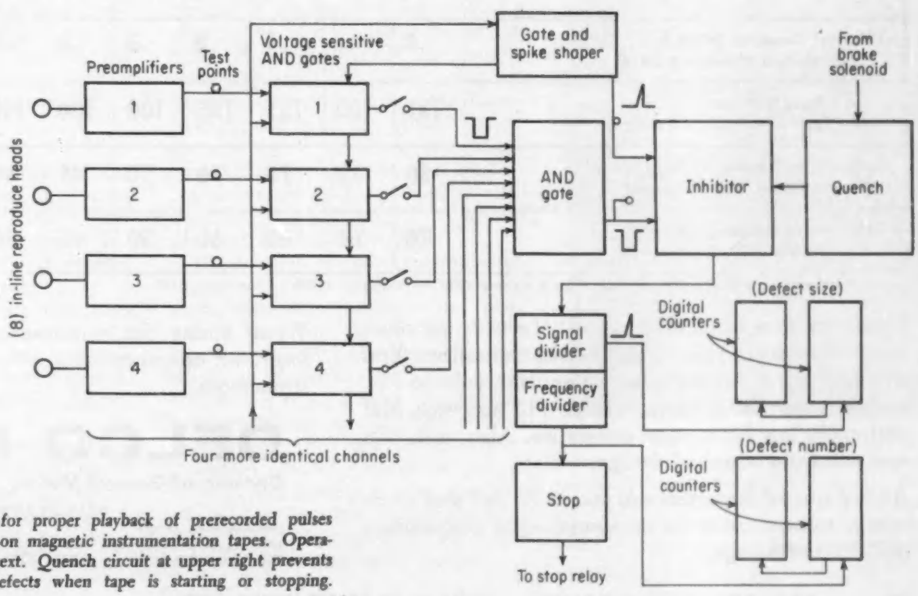
Following each reproducing head is a separate preamplifier, with an overall gain control, and an adjustable feedback control to balance the outputs of the preamplifier with one another. Each preamplifier feeds the control grid of a separate gating tube. Control grid bias on the gating tubes is normally high enough to cut off the tube, and is adjustable to form a threshold control. The bias can be set so that any percentage of full output from the preamplifiers will overcome the bias and make the tube conductive.

The suppressor grid is also biased to cut-off, except when it receives a positive square wave from a controlled univibrator and shaper. Thus the gating tube is an AND circuit, and conducts only when the bias of both grids is overcome simultaneously.

The output of the gating tubes goes to another AND gate, which produces a negative output only when it receives pulses from all of the active reproduce channels. The output of this AND gate keeps spikes from the univibrator and shaper away from the fault counters and the tape-stop relay.

If there is a defect on the tape sufficient to lower the reproduced signal in any head below the threshold on the gating tube, the cathode follower fails to quench the inhibitor, and a spike or spikes pass to the counter and relay circuits. One counter indicates the number of pulses missing in a defect; this count is proportional to the size of the defect. A second counter, operated through a frequency divider, counts the number of defects on a reel of tape. The relay can be set to stop the machine for a single defect.

With this testing system it can be readily determined whether any one pulse in the more than 40 million on a tape reel fails to reproduce properly. Audio Devices is rejecting tape for computer use if one pulse on the reel is dropped out.



This system checks for proper playback of prerecorded pulses from eight channels on magnetic instrumentation tapes. Operation is described in text. Quench circuit at upper right prevents counting of false defects when tape is starting or stopping.

IMPROVED CHARACTERISTICS

...OF SPECIAL INTEREST TO CONTROL ENGINEERS

DELCO HIGH POWER TRANSISTORS

UNEXCELLED FOR RELIABILITY, POWER HANDLING, SIMPLICITY AND VERSATILITY

TYPICAL CHARACTERISTICS AT 25°C.

	2N1100†	2N1099‡	2N174A*	2N174	2N173	2N278	2N277	2N443	2N442	2N441
Maximum Collector Current	15	15	15	15	15	15	15	15	15	15 amps
Maximum Collector Voltage (Emitter Open)	100	80	80	80	60	50	40	60	50	40 volts
Saturation Resistance	.02	.02	.02	.02	.03	.03	.03	.03	.03	.03 ohms
Thermal Gradient (Max.) (Junction to Mounting Base)	.8	.8	.8	.8	.8	1.0	1.0	1.0	1.0	1.0 °C/watt
Base Current I_B (V_{EC}=2 volts, I_C=5 amps)	135	100	135	135	100	100	100	150	150	150 ma
Collector to Emitter Voltage (Min.) Shorted Base (I_C=.3 amps)	80	70	70	70	50	45	40	50	45	40 volts
Collector to Emitter Voltage Open Base (I_C=.3 amps)	70	60	60	60	50	45	40	55	45	40 volts

*Designed to meet MIL-T-19500/13A (Jan) 8 January 1958 †Formerly DT100 ‡Formerly DT80

Check your requirements against the *new, improved* characteristics of Delco High Power transistors. You will find improved collector-to-emitter voltage . . . higher maximum current ratings—15 amperes, and extremely low saturation resistance. Also, note the new solid pin terminal design.

And of special importance to you is the fact that diode voltage ratings are at the maximum rated temperature (95°C.) and voltage.

Write today for engineering data on the *new, improved* characteristics of *all* Delco High Power transistors.

DELCO RADIO

Division of General Motors • Kokomo, Indiana

BRANCH OFFICES

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1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

 CIRCLE 60 ON READER-SERVICE CARD

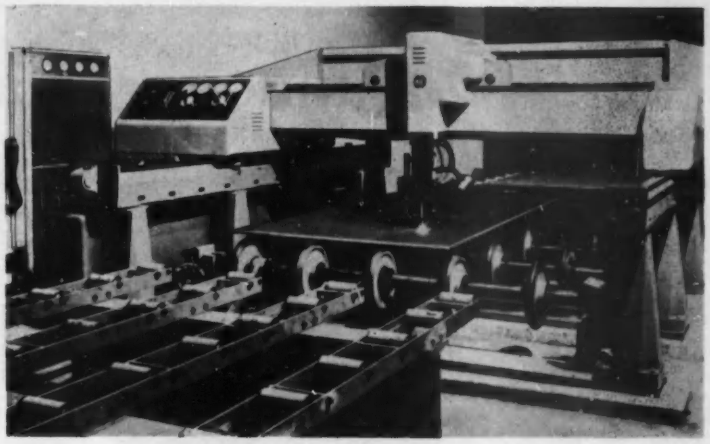


FIG. 1. The prototype model of the automatic flame profile cutter accommodates plates up to 6 ft by 7 ft. The panels mounted on the gantry contain both electrical and gas control; on the left is the gas supply unit, which minimizes variations in supply pressure of the fuel gas and oxygen.

Programming Flame Cutters Pays Off For Shipyards

DEREK BARLOW, CONTROL ENGINEERING, London

A major bottleneck in shipbuilding is preparation of plates with curved profiles. Normally, full-size templates involving some five different operations, each with their attendant errors, are manufactured first, and from them the finished plates are cut.

A computer-controlled flame cutter, Figure 1, developed jointly by British Oxygen Gases and Ferranti, Ltd., of England, eliminates all stages between the drawing board and the final cutting machine. In the prototype machine now undergoing trials, 6-ft-by-7-ft steel plates up to 2 in. thick are cut to an accuracy of 1/64 in. over a length of 30 ft at a speed of 20 in. per min.

A planning sheet giving the positions of all change points, the centers and radii of curves, and information on kerf width and cutting speeds is prepared straight from the drawing. This information is coded by a teleprinter onto standard five-channel punched tape. A data processing computer (not necessarily located at the shipyard) computes from the punched tape the movements and rates for each axis, recording these as time modulated pulses on magnetic tape.

Associated with the cutting machine is the machine control console, which accepts the magnetic tape. Command signals from the tape are fed to servos controlling the position of the cutting nozzle. A rack and pinion transmits the longitudinal movement while a leadscrew transmits the lateral movement. Feedback units on the pinion and leadscrew check position.

The positioning is a version of the standard Ferranti system; additional features, such as continuous nozzle height sensing, automatic ignition and flame monitoring (Figure 2), are required for flame cutting.

The nozzle is kept at constant height above the plate by a h.f. sensing system. A change in inductance of a copper ring, due to variations in the plate thickness, adjusts the nozzle assembly position. The ring is mounted on a probe around the flame. Micro contacts on the probe shut off the machine if the probe strikes any obstruction on the plate. Gas ignition is from a spark discharge from an insulated electrode adjacent to the nozzle; photocells monitor the flame.

In operation, the start button brings the nozzle to the datum point and a motorized conveyor runs the plate against stops on the machine. The tape deck is switched on and the spark discharge ignites the gas. After a preset heating time, cutting proceeds automatically and the finished plate is discharged to the prefabrication area.

Future models, available in 18 months, will have twin cutters capable of turning out left- and right-hand plates up to 12 ft by 40 ft. Estimates put savings as high as 30 percent.

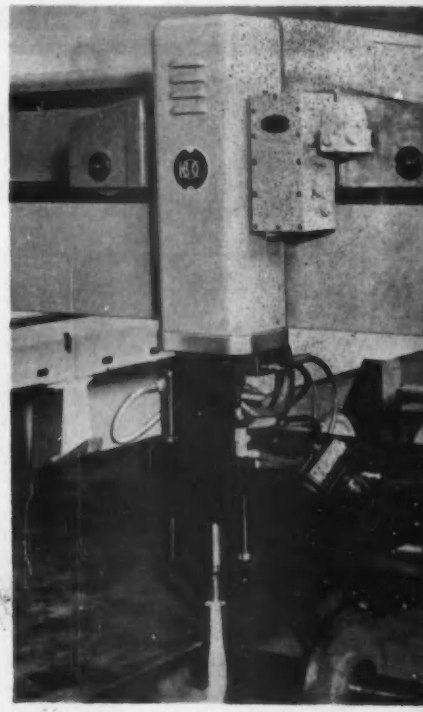
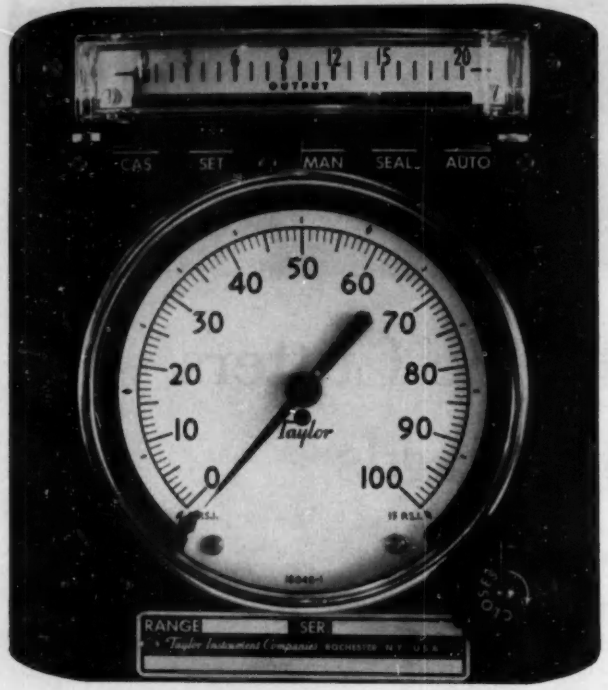


FIG. 2. Three protective devices surround the flame. On the left is the inductive probe, which maintains constant height between the nozzle and plate. To the right of the nozzle is the spark ignition electrode, and to its right is the photoelectric flame monitor

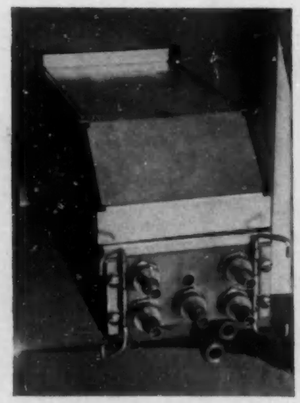
Taylor announces a new low cost

TRANSET* INDICATOR



FOR MOST ECONOMICAL INDICATION AND CONTROL

Team up the new 82KF Series Transet Indicator with the Sensaire* Temperature Transmitter or the No. 200T Fixed Range Differential Pressure Transmitter.



Rear view, showing plug-in facilities for Transcope, Triscope or Transet Controllers.

Indicator gage snaps in for easy removal without disturbing piping or process control.

This latest addition to the Transet family of instruments is designed to permit plug-in mounting of either the bellows type Transcope*, Triscope* or stacked diaphragm type Transet Controllers.

Using accurate, time-proven components, it has exceptionally stable and driftfree set point adjustment. Choice of Bourdon or high accuracy Niafram elements, according to process requirements.

Same cutout as the 66K and 86J Transet Indicators and Recorders, and can be quickly adapted to fit the Transcope Recorder cutout.

Maintenance and servicing is particularly easy. The snap-in indicator gage can be removed for checking without disturbing piping or process control.

Precision adjusting of set point, with regulator having metallic feed-back element and Ni-Span spring, insures stable output even with wide temperature variations.

Piston type selector valves with "O"-ring seals give leakless transfer. Positive positioning is assured by lever switching with definite mechanical stops.

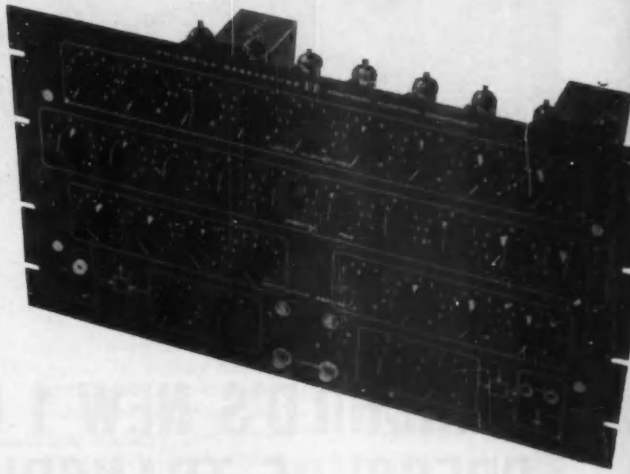
Set point transmitter and switching blocks are the same as used in the famous Transcope Recorder.

For full details of this precision built but inexpensive instrument see your Taylor Field Engineer or write for information to Taylor Instrument Companies, Rochester, New York or Toronto, Ontario.

*Trade-Mark

Taylor Instruments MEAN ACCURACY FIRST

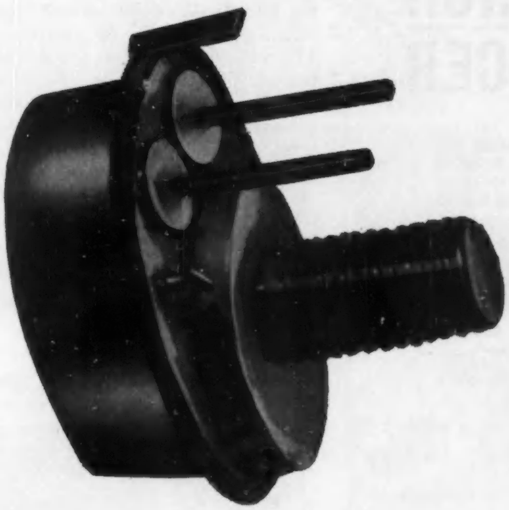
NEW PRODUCTS



"FUNCTION FITTER" aids analog computing.

Called the Model FF Function Fitter, this versatile, self-contained analog computer component simulates arbitrary functions of the input voltage. It features 10 straight-line segments with adjustable tangent parabolic rounding, as well as adjustable slopes, break points, and offset. The tangent parabolic rounding feature permits faithful simulation of smooth functions with "infinite" resolution, while the break-point adjustment provides greater accuracy in regions of large slope change. Mounted on a 10½-in. rack panel with its own operational amplifiers, the unit draws 80 watts at 115 vac and sells for $875.—George A. Philbrick Researches, Inc., Boston, Mass.

Circle No. 200 on reply card



NEW TRANSISTORS switch up to 1 kw.

Two new silicon transistors, for switching and amplifier applications, combine high current and voltage ratings with low saturation resistances. Of p-n-p construction, the units are rated at 2 and 5 amps respectively, have a 30-to-300-volt collector-to-emitter voltage range, and can switch power up to 1 kilowatt. Maximum saturation resistance of the 2-amp unit is 0.7 ohm; that of the 5-amp unit, 0.5 ohm.

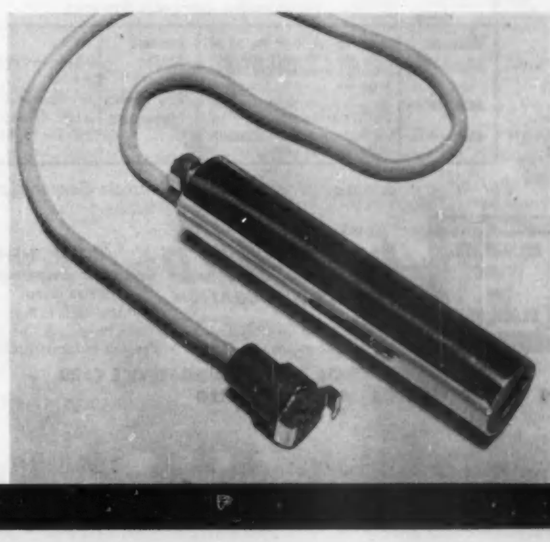
Each is hermetically sealed in a welded stainless-steel case and provided with a threaded stud for mounting on an external heat sink. Maximum overall dimensions are 1¼ in. in diameter by 1$\frac{7}{16}$ in. long.—Westinghouse Electric Corp., Pittsburgh, Pa.

Circle No. 201 on reply card

COMPACT PICKUP has self-contained circuit.

The Proxor, a new solid-state proximity switch, measures just ¾ in. in diameter by 4 in. long. Yet encapsulated within this chrome-plated case are the sensing coils and associated bridge, a transistor oscillator, a two-stage transistor switch, and a miniature printed-circuit board. Models are available for both magnetic and nonmagnetic metals. Typical applications include noncontacting limit switching, go, no-go gaging, and automatic indexing. With gear teeth moving through the sensing zone, the Proxor becomes a digital tachometer for speeds up to 7,200 counts per min. A screw adjustment varies the sensing zone from 0.001 in. to over 0.1 in. to facilitate installation.—Parametrics, Costa Mesa, Calif.

Circle No. 202 on reply card

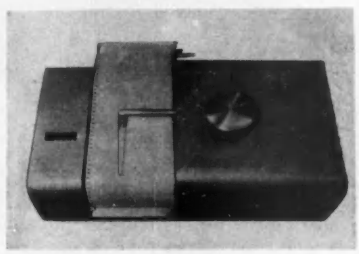


DATA HANDLING & DISPLAY

LOW-COST COUNTERS

A brand new line of three- and five-decade electronic counters, featuring power requirements of less than 25 watts, has been developed for totalizing and predetermined-count applications. Models will be available for 115-volt, 60-cycle, or self-contained battery operation. Use of all solid state and cold cathode components eliminates the need for any warmup time. Model 12A3P, shown above, weighs only 6¼ lb, consumes a total of 15 watts of power, and sells for around \$300.—Redford Corp., Lake Luzerne, N. Y.

Circle No. 203 on reply card

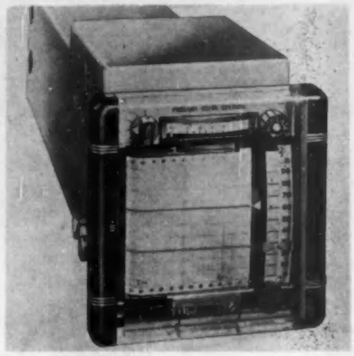


SEMI-AUTOMATIC

Designed for accurately integrating flow records from 3- to 4-in. strip charts, this portable planimeter features a simple cam change for conversion from linear to square-root operation. Chart feed is controlled by a foot-operated rheostat through a variable-speed electric motor. A manually positioned knob controls motion of the index point as the chart is ad-

vanced. Suitable for desk-top use, the device operates on 110 vac.–Royson Engineering Co., Hatboro, Pa.

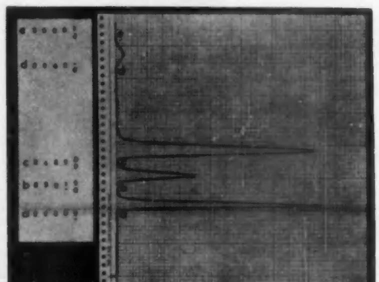
Circle No. 204 on reply card



TWO-PEN RECORDER

Designed to fit a 5-in.-square panel cutout, this new all-electronic recorder provides a record of two variables on a single strip chart. The instrument cuts costs, conserves panel space, and permits "one-glance" checks on a pair of related variables. A control set-point, alarm contacts, or both, for either of the variables are optional. Sensitivity is 0.1 percent or better; error, within ½ percent of full scale.–Swartwout Co., Cleveland, O.

Circle No. 205 on reply card



INTEGRATES PEAKS

Designed as an accessory for the Model 154-C Vapor Fractometer, the Model 194 Printing Integrator can easily be adapted for use with other gas chromatography systems. It provides a digital record on standard adding-machine tape of the area under the peaks on the chromatographic chart. In automatic operation, one of the integrator's three modes, the tape

Centralized Air Data Computing System | Refrigeration Package | Ram Air Turbine

North American Aviation's twin-jet A3J "Vigilante" is the Navy's newest attack weapon system . . . an all-weather, carrier-based, 30,000 lb. thrust aircraft which delivers both conventional and nuclear weapons from high or low altitudes at supersonic speeds.

Contributing to the success of the first aircraft produced under the Navy's weapon system management concept is the following AiResearch equipment:

AiResearch Centralized Air Data Computing System provides information for the major flight data subsystems dealing with bombing, navigation, engine inlet control, radar, automatic flight control and includes cockpit indicators showing true air speed, altitude and engine inlet air temperature.

AiResearch Environmental System Components for personnel and compartment air conditioning and pressurization include: cabin pressure regulators, safety valves, cabin refrigeration package, equipment compartment refrigeration package, primary heat exchangers, pressure suit heat exchangers and water-alcohol tanks for evaporative cooling.

AiResearch Ram Air Turbines provide power for operation of surface controls, instrumentation and landing gear in case of emergencies. Also included are miscellaneous valves and electro-mechanical equipment.

Systems engineering, support services and systems management have enabled AiResearch to integrate these vital subsystems into North American's A3J.

ENGINEERING REPRESENTATIVES: AIRSUPPLY AND AERO ENGINEERING, OFFICES IN MAJOR CITIES

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

travels continually at the same rate as the chart paper, permitting side-by-side comparison of records, as shown in the photo above.—Perkin-Elmer Corp., Norwalk, Conn.

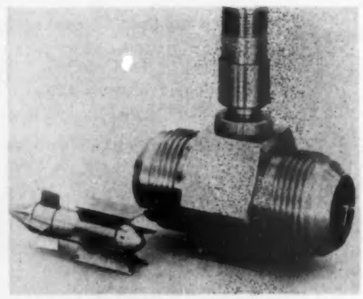
Circle No. 206 on reply card

PLUS . . .

(207) A numerical control tape preparation system, available from the Industrial Control Section of **Bendix Aviation Corp.**, automatically prepares control tapes for two and three-dimensional contour machining. . . . (208) **Philco Corp.** and the **Uptime Corp.** jointly announce a new **high-speed punched card reader**, the Speedreader 2000. . . . (209) Pressure, draft, differential, and level are measured, indicated, and transmitted by a new 7-in. **pneumatic indicator** recently introduced by **Bailey Meter Co.**

Circle No. 207, 208 or 209 on reply card

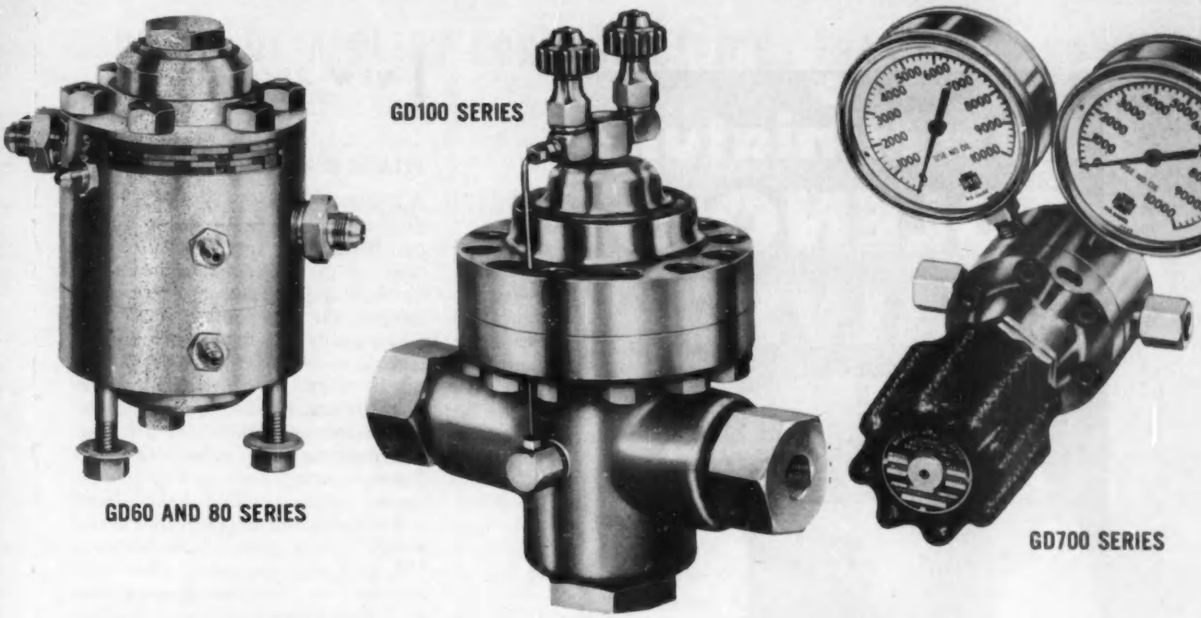
PRIMARY ELEMENTS & TRANSDUCERS



NO FRICTION PROBLEM

The rotor in this new turbine-type flow pickup floats entirely on a fluid film. Since no bearing is used, wear and error effects from radial or thrust friction are eliminated. Manufacturer claims this new design improves rangeability, reproducibility, and service life without sacrificing performance. Output is accurate to within ¼ percent of the actual flow rate, even with range changes of 10 to 1. Maximum flow depends on the acceptable pressure drop.—Waugh Engineering Co., Van Nuys, Calif.

Circle No. 210 on reply card



Control gases safely, accurately

to 15,000 psi and 200,000 scfh with

VICTOR REGULATORS

You get precise regulation of high pressure gases with large flow rates, because Victor employs gas pressure to control the regulating diaphragm. The result is accurate delivery from 5 to 15,000 psi with inlet pressures to 15,000 psi . . . plus ability to obtain flows in excess of 200,000 scfh at maximum inlet and outlet pressures. Chart below shows operating range of standard models.

MODEL NO.	MAX. INLET PSI	MAX. OUTLET PSI	FEATURES	MAX. FLOW SCFH
GD10	3,600	500	Single adjustment regulator control	15,000
GD30	2,500	2,500	Load & bleed valve control	25,000
GD31	3,600	3,600	Load & bleed valve control	36,000
GD61C	2,500	2,500	Load & bleed valve control	10,000
GD62C	3,600	3,600	Load & bleed valve control	12,000
GD65	6,000	6,000	Load & bleed valve control	15,000
GD65C	7,000	7,000	Load & bleed valve control	15,000
GD80A	5,000	5,000	Load & bleed valve control	30,000
GD81A	10,000	10,000	Load & bleed valve control	50,000
GD86R	10,000	10,000	For remote control only	75,000
GD100R	6,000	6,000	For remote control only	240,000
GD100	6,000	6,000	Load & bleed valve control	240,000
GD700	7,000	7,000	Single adjustment regulator control; self relieving	15,000
SR10	3,600	1,000	Small, spring loaded regulator	200
LR20B	7,000	7,000	Spring loaded regulator; self relieving	120

Operating temperature range: −67°F. to +250°F.

. . . Yours for the asking
Take advantage of Victor's long experience with high pressure gas regulation to help solve your special problems involving flow rates, delivery pressures, corrosive fluids and temperature compensation. Write, wire or phone us today. No obligation.

All models listed are field proved. Most are designed for panel mounting or remote control. They regulate all non-corrosive gases, including oxygen. Stainless steel models available for corrosive gases and pressures above 10,000 psi. For complete specifications, write for Victor High Pressure Regulator sheets.

VICTOR for regulators

VICTOR EQUIPMENT COMPANY

Mfrs. of High Pressure and Large Volume Gas Regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

53

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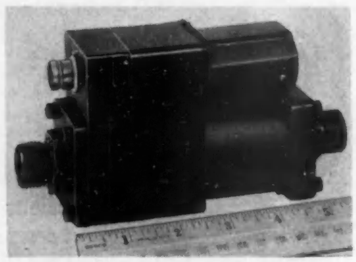
J. C. Menzies & Co., Wholly-Owned Subsidiary

CIRCLE 67 ON READER-SERVICE CARD

PHASE SENSITIVE

A new transducer, called a Dirpot (for displacement/reverse-polarity/dc-output transducer), uses the basic principle of the differential transformer, in which displacement of an armature modifies the flux paths in an E-core. The ac output is then demodulated, making it possible to determine the side of neutral on which the armature is positioned by the polarity of the output voltage. This extremely compact unit, including differential transformer with armature, isolating transformer, phase-sensitive demodulator, and demodulator supply transformer, weighs only 1¼ oz and draws 30 ma at 115 volts, 400 cps. Only other connections are for the phase-sensitive dc output.—Pneuma-Serve, Ltd., Toronto, Canada.

Circle No. 211 on reply card



FLOWS TO 5,000 LB PER HR

This 2½ lb miniaturized mass flowmeter transmitter has been designed for use in new, high-speed jet and turbo-prop aircraft. A self-contained frequency compensator permits operation on almost any 400-cycle supply. Temperature range is minus 55 to plus 121 deg C. New transmitter can be used with the DJ-96 flowrate indicator.—General Electric Co., Schenectady, N. Y.

Circle No. 212 on reply card

PLUS . . .

(213) A 3-oz variable reluctance pressure pickup, available in range from 0 to 5,000 psi gage, differential, or absolute, and offering excellent performance under extreme environmental conditions, has been announced by **Tavis Instruments, Inc.**, Pasadena, Calif. . . . (214) **Schutte & Koerting Co.**, Cornwells Heights, Pa., now offers a line of metal tube rotameters for use with hazardous and

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

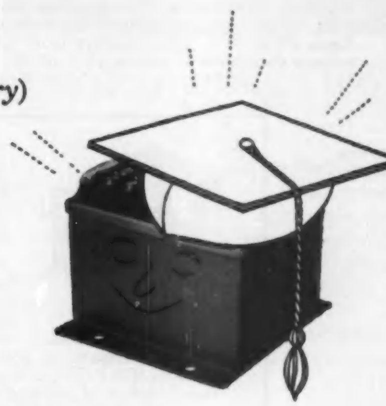
HIGH SPEED STATIC SWITCHING *(at half the price)!*

Sylvania Electric Products Co. engineers have just replaced an electronic relay, two small mechanical relays, a limit switch, and a separate power supply with a single CONTROL switching reactor which costs only half as much! They did it by taking advantage of the multiple windings on a CONTROL switching reactor—equipment which, because of its static operation, never wears out. Seems a high speed assembly operation on one of Sylvania's complex, highly automated vacuum tube production machines calls for a magnetic clutch to drive an index table. The clutch orients the work part by rotating it until current flows through two properly located contacts. Our CONTROL switching reactors not only cut costs in half, but do a job that the relays couldn't do: provide the ultra high speed signal necessary for proper switching in the automated assembly. *It worked so well Sylvania said, "I'll be switched!" We said, "With a 10,000 to one switching ratio, and ratings of 15, 75, 150 and 300 VA, most anything for control can be!"*

ONCE UPON A TIME . . . *(time delay, that is)*

Versatile, we are too! The same type of CONTROL switching reactors that work so well for this high speed switching also are used by Sylvania engineers to eliminate production breakdowns caused by relay failures in time delay circuits. Many pneumatic time delay relays on their production machines were dying young (three months of age or less). CONTROL switching reactors (which, naturally, never wear out) not only have no moving parts, but do a dandy job with time delay relaying, easily handling 6,000 closures per hour. Sylvania happily expects its CONTROL reactors to last twenty years. *"Right now," Sylvania says, "we're not too worried about what will happen after that." Need you be any more worried than they?*

LOGIC, MY DEAR WATSON *(. . . is elementary)*



Our educated switching reactors are masters at logic—the kind that gets built into automatic control operations. AND, OR, NOT, MEMORY and TIME DELAY—all are built into these high IQ reactors. By employing several isolated control windings, one reactor can translate many inputs (from push buttons, limit switches or other reactors, for instance) to any logic needed to switch very appreciable loads. And are they easy to use! Order standard units right from the catalog. You need no high falutin' systems engineering or auxiliary hardware (single purpose logic units, preamplifiers or transformers). *No wonder logical people order our logic-providing switching reactors. Can we send complete details to you?*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.

Dept. CE-54, BUTLER, PENNSYLVANIA

high-pressure fluids. . . . (215) **Librascope, Inc., Glendale, Calif.,** recently introduced a **shaft-position-to-digital encoder** that provides 10-bit resolution with no ambiguity.

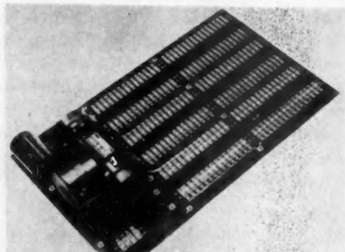
Circle No. 213, 214, or 215 on reply card

CONTROLLERS, SWITCHES & RELAYS

THRUST CONTROLLER

Shown is a new hydromechanical controller capable of sensing and correcting small errors in thrust chamber pressure in liquid-propellant rocket engines. Components include a two-stage pressure regulator for obtaining an accurate reference, a high-gain error sensing diaphragm, and a two-stage hydralic amplifier. A pneumatic phase-lead device provides extra damping during rapid pressure changes at, for example, startup. Remote changes in thrust level are handled by a built-in torque motor.—Bendix Aviation Corp., South Bend, Ind.

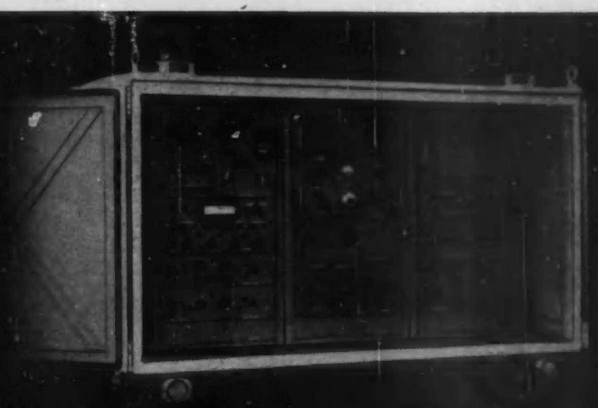
Circle No. 216 on reply card



HIGH-SPEED SAMPLING

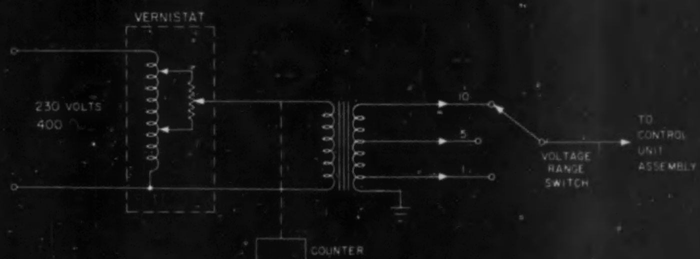
This motor-driven precision switch is 13 in. wide and 22¼ in. long, and has six poles with 30 nonshorting or 60 shorting channels per pole. Match contact plates provide simultaneous

Eclipse-Pioneer designs test set for B-58 Hustler autopilot system...



An automatic flight control system that "thinks ahead" of the pilot is a "must" for the Air Force's Convair B-58 Hustler — world's fastest bomber. "Brain" of this system — developed by Eclipse-Pioneer Division of Bendix Aviation Corporation — is a compact control unit assembly in which all flight factors are continuously and instantly translated into commands to control surfaces. To check out this assembly quickly and conveniently, a mobile test set has also been designed — and **Vernistat is there** as an accurate source of test voltages in simulating a number of signals and commands.

...and Vernistat* is there!



Vernistat a.c. potentiometers were selected for several of the test panels because of their unique combination — in one component — of reliability, low output impedance, low phase-shift, and high linearity. In the typical application above, a Vernistat is mechanically-geared to a counter to provide an output voltage that can be accurately set to the required value. Low phase shift from input to output is maintained by the Vernistat's inherent design. And need for an isolation amplifier — with its added cost and disadvantages — is eliminated.

Doesn't Vernistat thinking belong in your system design too?

In this application, Vernistat thinking by Eclipse-Pioneer engineers helped solve a design problem with reduced equipment cost, system complexity, and design time. Cost was only a quarter of that of an alternative method utilizing conventional potentiometer, isolation amplifier, and d.c. power. Use of fewer components reduced system complexity, increased accuracy and reliability, and saved valuable design engineering man-hours.

In servo systems, analog computers, and similar uses, you too can obtain such results with Vernistat a.c. potentiometers. With this new concept in relating shaft position to voltage, you get low output impedance (as low as 45 ohms) with high input impedance (as high as 200,000 ohms), plus high resolution (to 0.004%), low phase shift (as low as 0.2 minutes), and high linearity (to 0.01%).

In addition to precision a.c. potentiometers, Vernistat products include function generators (adjustable non-linear potentiometers), and variable ratio transformers. Military specifications are met by the wide selection of models available.

Write today for complete details and specifications on Vernistat precision products.

*vernistat® — *a new design concept that unites in one compact device the best of both the precision autotransformer and the multiturn potentiometer.*

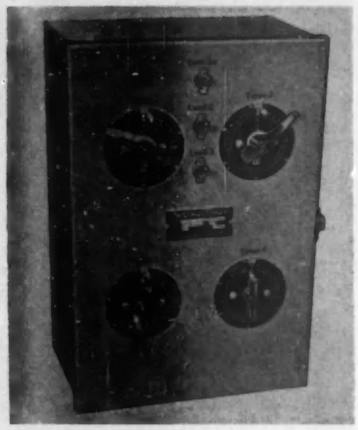
Perkin-Elmer *Corporation*

vernistat division

766 Main Avenue, Norwalk, Conn.

sequential sampling of corresponding circuits within close phasing tolerances. The hysteresis motor supplied with the switch operates on 115 volts, single phase, 60 cycles. Channel sampling rate is 1 rps.—General Devices, Inc., Princeton, N. J.

Circle No. 217 on reply card



DIAL-SET TIMER

Shown is one model of this company's Type 3400 synchronous-motor-driven cycle timers. Available in 13 timing ranges from 60 sec full dial to 60 hours, the units feature an accuracy within 0.2 percent. Circuit combinations include time delay, multiunit sequence control, percentage time, and elapsed time indication. Load contacts are rated at 10 amp and isolated to permit control of loads operating at voltages other than the 110-volt timer supply.—National Time & Signal Corp., Detroit, Mich.

Circle No. 218 on reply card

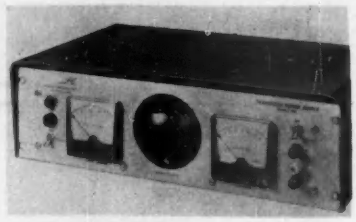
PLUS . . .

(219) Precision, lightweight, electromechanical timing devices, called **Sequential Programmers**, have been developed by **Pomona Electronics Co., Inc.**, Pomona, Calif. . . . (220) **Servonics Engineering Services Co., Inc.**, Sherman Oaks, Calif., offers an ultra-fast **impact switch** with a controllable time limit range of 90 to 200 microsec. . . . (221) An industrial-type **miniature relay**, by **General Electric Co.**, Schenectady, N. Y., features a rugged 14-pin header that mates with an equally rugged phenolic socket for panel mounting. . . . (222) **Micro Switch Div., Minneapolis-**

Honeywell Regulator Co., Freeport, Ill., recently announced a miniature quick-connect switch with a 10-amp rating.

Circle No. 219, 220, 221 or 222 on reply card

POWER SUPPLIES



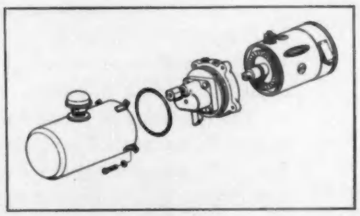
STABLE SUPPLY

The T-200 Series consists of eight new transistorized power supplies, one of which is pictured above. Output ranges are suitable for both transistor and vacuum-tube circuitry. Design provides protection against shorted outputs.

Characteristics:

Regulation: 1 percent or 30 mv
Recovery time: 50 microsec
24-hour stability: within 0.2 percent
Efficiency: 75 percent at full output
Output impedance: as low as 0.01 ohm
Size: 19 in., rack or cabinet
—Armour Electronics, Inc., Los Angeles, Calif.

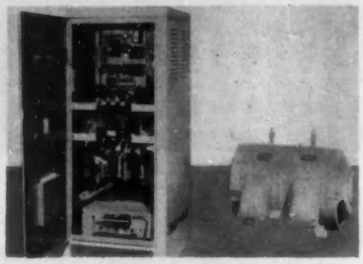
Circle No. 223 on reply card



HYDRAULIC POWER

Pictured is an exploded view of a new low-cost hydraulic power pack. Elements include an electric motor drive, hydraulic gear pump with integral relief valve, check valve, and reservoir, all in one compact assembly. Models are available for 6-, 12-, or 24-vdc operation. Pump capacities range from 0.36 to 0.8 gpm; reservoir capacities, from 0.43 to 1.0 gal.—Wooster Div., Borg-Warner Corp., Wooster, Ohio.

Circle No. 224 on reply card



400 CPS FOR COMPUTERS

For years 400-cycle power has been a standard in the aircraft industry. This new 400-cycle motor generator supply, however, is designed specifically for business data processing equipment. Manufacturer claims it permits a 50-percent reduction in size on all the magnetic components in a computer.

Characteristics:

Input: 440/480 volts, 60 cps, three-phase
Output: 115/200 volts, 400 cps, three-phase
Power rating: 50 kva at 0.8 pf
Voltage regulation: within 1 percent
Frequency regulation: within 4 to 19 cps, depending on load
—Inlet Div., Leach Corp., Compton, Calif.

Circle No. 225 on reply card

DELIVERS 36 TO 72 VDC

Another in this company's line of transistorized power supplies, the Model SC-3672-1 provides a 36-to-72-volt, 0-to-1-amp output. Features include over-temperature protection, continuously variable output voltage, and continuous operation into a short circuit.

Characteristics:

Regulation: 0.1 percent or 0.003 volt
Ripple: under 1 mv rms
Recovery time: less than 50 microsec
Temperature coefficient: less than 0.05 percent per deg C
Output impedance: under 0.08 ohm
—Kepco Laboratories, Inc., Flushing, N. Y.

Circle No. 226 on reply card

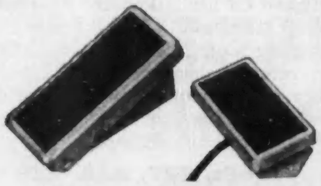
PLUS . . .

(227) Specs on a new line of transistorized, regulated dc supplies with ranges from 5-8 to 26-30 volts, have just been released by **Universal Electronics Co.**, Santa Monica, Calif. . . . (228) **Spectrol Electronics Corporation**, San Gabriel, California, has just recently introduced four new transis-

HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

ENGINEERING NEWS



FOOT SWITCHES SIMPLIFY COMPLEX SWITCHING PROBLEMS

For many control operations, the foot is often quicker than the hand and a whole lot more convenient—especially where many switches must be attended or where the operator's hands must be freed for other more exacting chores.

Foot switches can often handle heavy-duty multiple-pole, 2 or 3-position switching more reliably, more conveniently, and with decided savings in panel space compared to hand-operated switches or relay circuits.

The two Hetherington Foot-operated Switches illustrated can be supplied in a wide number of single and double-pole circuit arrangements with ratings up to 15 amps, 115 volts ac. Sturdy aluminum frames have a non-skid abrasive compound on treadles.

Circle 77 on Reader-Service Card

SPACE-SAVER LIGHTS
for Standard or Edge-Lit Panels

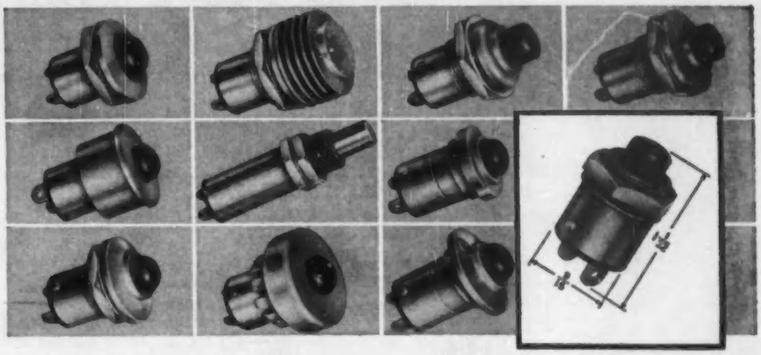
Only 1¼ inches from terminal to lens, these tiny indicator lights give bright and moderately wide-angle visibility in minimum front-panel area. Colored plastic lenses unscrew from the front for quick replacement of AN3140 lamps; 6, 14, 18, or 28 volts.

One-piece terminal and contact assemblies are solidly molded as an integral part of the assembly. Lamp circuits cannot be broken by pulling on the terminal.

Full details on Hetherington Series L1000 (for regular panels), or Series L2000 (for edge-lit aircraft panels) are in Bulletin L-1.

Circle 78 on Reader-Service Card

THE SWITCH WITH THE 1,800 PIECE WARDROBE



Take any Hetherington "JR"-Series Switch, screw on any of 14 anodized aluminum adapters such as those above, and you have a totally different unit . . . in style as well as in mounting characteristics.

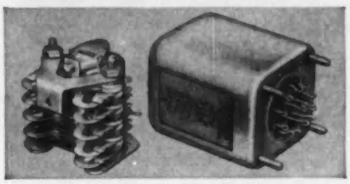
Most adapters can be furnished with any of 2 or 3 different auxiliary push buttons to meet individual requirements. In addition, any of 7 or 8 colors can be added to either or both the adapter or button —making a total of more than 1,800 possible combinations for *each* of the six basic switch circuits.

Adapters range from standard flange-mounting types to force-fit, blind-hole, and molded stick-grip types. Many can be engraved in ⅛-inch letters to indicate switch function.

"JR"-Series Switches use the positive Hetherington snap-action mechanism rated for 17 amps at 28 volts dc, or UL Inspected for 15 amps at 115 volts ac.

Complete ratings, specifications and dimensions of all switches and adapters are shown in Bulletin S-5.

Circle 80 on Reader-Service Card



JET-AGE RELAYS
Meet Tough Shock and Vibration Specs

Designed originally to withstand the extreme shock, vibration, and high temperatures of high altitude aircraft, missiles, and rockets, these Hetherington G-Series Relays have proved remarkably successful and economical for many less exacting earth-bound applications as well. Typical aircraft types with up to 6 single-throw or 4P-DT contacts, withstand 20G vibration at over 500 cycles. Temperature barriers have been raised to 600°F in many specific types. Single and multiple-unit assemblies are available in a variety of open, dust-proof, and hermetically-sealed types with contact ratings up to 10 amps.

Industrial models for less critical applications are available at correspondingly lower prices.

Details are in Bulletin R-1.

Circle 79 on Reader-Service Card

WHEN YOU NEED SWITCHES IN A *HURRY*

Small quantities of many Hetherington products are now stocked for same-day delivery on both the East and West Coasts. See your local Hetherington sales engineer for an up-to-date list of stock items.

HETHERINGTON INC. DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

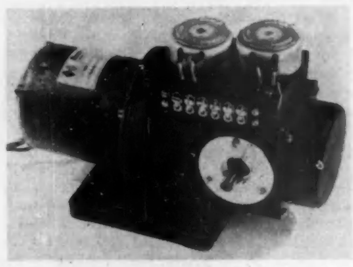
. . . for jobs where a better switch is far-sighted economy

A Controls Company of America Subsidiary

torized printed-circuit converter-inverters to replace motor-generator and vibrator-type devices. . . . (229) **Mercury battery packs,** by the Mallory Battery Co., North Tarrytown, N. Y., are designed for use as low-cost secondary voltage standards. . . . (230) **Perkin Engineering Corp.,** El Segundo, Calif., has recently developed a 24-32-volt, 100-amp, completely transistorized dc power supply which operates from a 208-volt, three-phase input.

Circle No. 227, 228, 229 or 230 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



THREE-SPEED DRIVE

Any three speeds, forward or reverse, from 0 to 3,600 rpm, are provided by this new solenoid-operated, variable-speed drive. Two standard motor sizes cover the range from 1/70 to ¼ hp. The solenoid control permits shifting from one speed to another in less than $\frac{1}{10}$ sec. Repeatability and accuracy are within 0.5 percent. Units feature a constant output torque and efficiency between 85 and 95 percent. —Humphrey, Inc., San Diego, Calif.

Circle No. 231 on reply card

BUBBLE-TIGHT SEAL

Specifically designed for rigorous missile applications, the Series V-27200 in-line solenoid valve uses Teflon for bubble-tight sealing against pressures up to 4,500 psi. Potted coils and a welded bobbin assembly permit reliable handling of cryogenic fluids, ethylene oxide, jet fuels, liquefied gases, and oils.

Characteristics:

Orifice sizes: 0.125 in. for 750 psi

1 MOVING-COIL AND DYNAMOMETER MOVEMENTS— No choppers, tubes, motors, slidewires, mirrors . . . provides utmost reliability. AC, DC, and Power movements.

2 UP TO 6 CHANNELS AVAILABLE — Curtiss-Wright Double Size Models are the only Rectilinear Strip Chart Recorders to offer up to 6 channels. Curtiss-Wright recorders provide simultaneous recording of two to six variables on a single chart in any combination of different types of movements.

3 SENSITIVITY DOWN TO 250 UA FOR DC. . . can be extended beyond 250 ua by DC amplifier (optional).

4 ACCURACY 1% FOR MOVING-COIL RECORDERS— Conservatively rated as ±1% of full scale for DC movements. Unusually low friction of pen against chart.

5 INKLESS AND INK RECORDING — Inkless recording is standard equipment on all but Miniature Models, on which it is optional. Cleanest, easiest method . . . a fine metal stylus "burns" the record into zinc coated chart paper. Instantly converted to ink recording.

6 RECTILINEAR RECORDING — A patented mechanical linkage changes angular motion of the needle into a straight line, giving an undistorted picture of the signal. Avoids errors and saves time.

7 THREE-SPEED TRANSMISSION plus 60:1 speed change from hours to minutes provides six interchangeable speeds in all.

8 MOTOR AND SPRING DRIVES — Sync motor, hand-wound short drive or electrically wound spring motors. Automatic chart rewind.

9 LIGHT AND COMPACT DESIGN — Small size and advanced design engineering of movement allows space and weight savings.

10 DUST-PROOF AND SPLASH-PROOF CASES— Steel cases decrease effect of stray magnetic fields.

11 SHOCK-PROOF MOVEMENT — Extra reliability when used in portable applications.

12 OUTSTANDING WORKMANSHIP — Improved design and meticulous attention to detail assure highest quality precision performance. All Curtiss-Wright recorders carry a one-year guarantee.

Curtiss-Wright . . . a new name in rectilinear strip chart recorders . . . offers you time proven advantages in precision operation. Made under licensing agreements with Metrawatt AG . . . a leading West German manufacturer of fine instruments for over 50 years . . . Curtiss-Wright recorders combine advanced design with highest quality workmanship. Moderate in price, these fine precision instruments are rugged and reliable . . . simple to operate. Write for complete information.

ILLUSTRATED ABOVE

A — MINIATURE SLIM MODELS 86 (portable) and 87 (flush). Weigh 9 lbs. 3¾" x 7⅛" x 8¾". $295.00 and up

B — STANDARD MODELS 81 (portable) and 82 (flush). Weigh 19 lbs. 7½" x 9⅞" x 8½". $445.00

C — MINIATURE SQUARE MODEL (85) Weighs 16 lbs. 5⅝" square, 12¾" deep. $330.00 and up

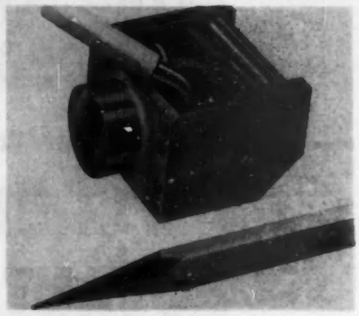
D — DOUBLE SIZE MODEL 83 (portable) and 84 (flush). Weigh 26 lbs. 12¾" x 9-13/16" x 8¾". $860.00 and up

ELECTRONICS DIVISION
CURTISS-WRIGHT
CORPORATION • CARLSTADT, N. J.

CIRCLE 82 ON READER-SERVICE CARD

rating and 0.020 in for 4,500 psi rating
Response time: 15 msec
Voltage ranges: 18 to 30 vdc
Dimensions: 1.25 by 2.60 in.
—Valcor Engineering Corp., Kenilworth, N. J.

Circle No. 232 on reply card

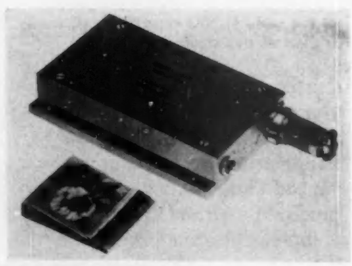


LINEAR OUTPUT

This Model 15 Linear Displacement Solenoid is said to be the first of its kind in production. A solenoid without permanent magnets, the unit will produce a linear mechanical motion directly proportional to its input current. Although it weighs only 4 oz, it has a mid-position force of 8 lb. Operating temperatures may range from minus 65 to plus 400 deg F. Hysteresis is approximately 1 percent. Currently, it is being used to position a hydraulic servovalve.—Midwestern Instruments, Inc., Tulsa, Okla.

Circle No. 233 on reply card

COMPONENT PARTS



COMPACT DESIGN

Ideal for airborne applications, this subminiature amplifier provides fixed

gains of 10, 30, or 100, preset at the factory. For use with high impedance transducers such as piezoelectric and capacitive devices, the unit is completely potted and features mil type output connectors. It has a broad range of 2 cps to 20 kc and a 5-mc current requirement.—Endevco Corp., Pasadena, Calif.

Circle No. 234 on reply card

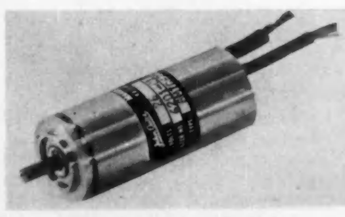
SUITED FOR MISSILES

Manufacturer claims this new high-gain transistor-magnetic servoamplifier suits high-speed, high-shock applications in both aircraft and missiles. It features silicon transistors in its servo-amplifier section, together with an integral fast-response magnetic amplifier.

Characteristics:

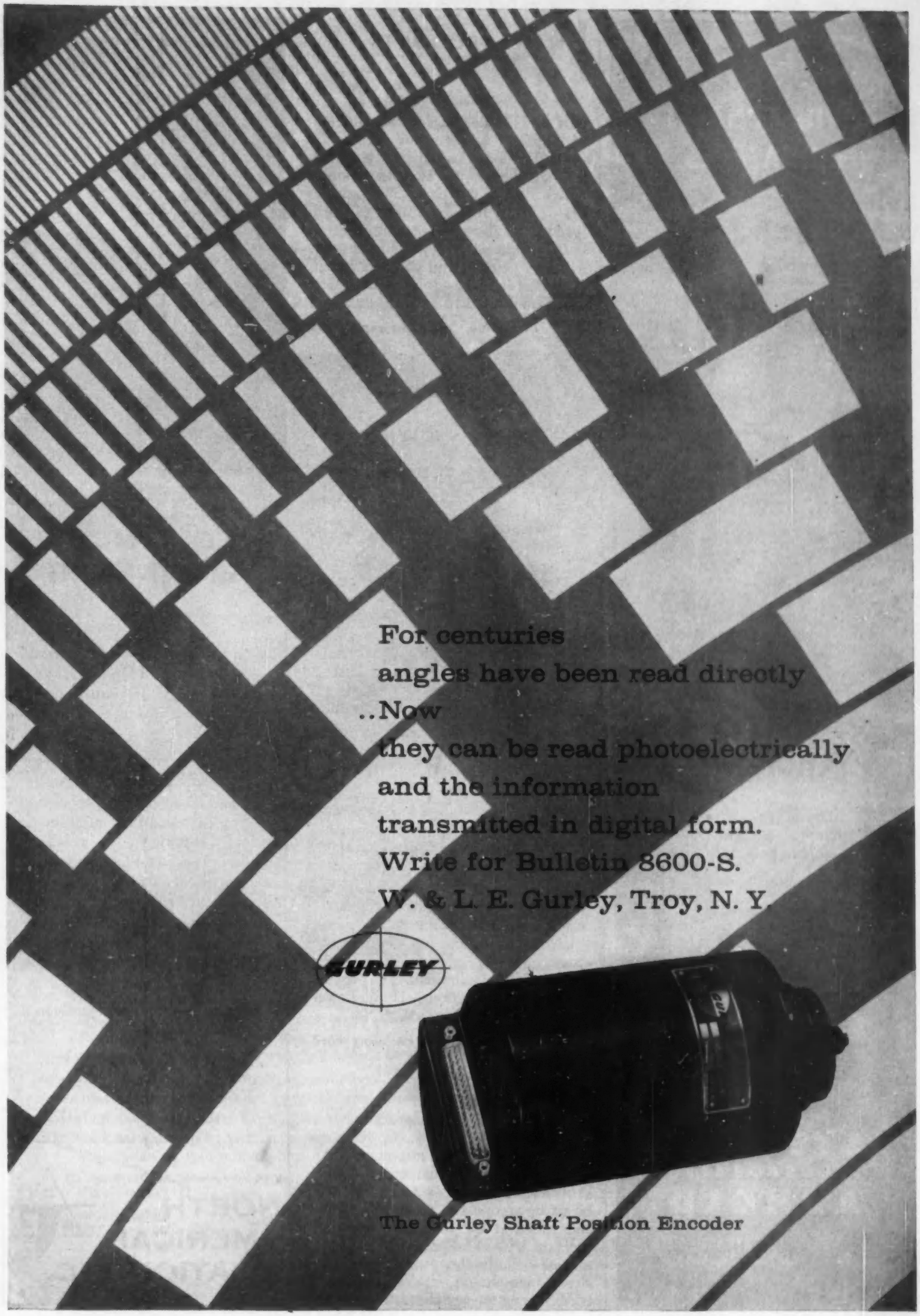
Power output: 3.5 watts
Phase shifts: 0 or 30 deg
Power input: 210 ma at 115 volts, 400 cps, and 30 ma at 27 vdc.
Input impedance: 10k ohms
Nominal gain: 2,500 or 2,000
Quadrature rejections: 20 db minimum
—Kearfott Co., Inc., Clifton, N. J.

Circle No. 235 on reply card



OPERATES AT 125 DEG C

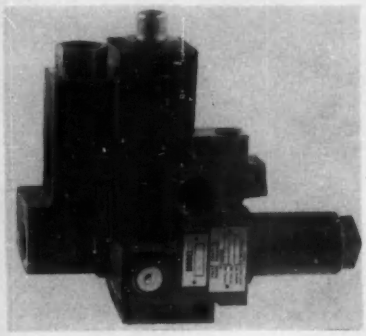
With an operating temperature of minus 55 to plus 125 deg C, this new size 8 servomotor tach generator meets the environmental requirements of


For centuries
angles have been read directly
..Now
they can be read photoelectrically
and the information
transmitted in digital form.
Write for Bulletin 8600-S.
W. & L. E. Gurley, Troy, N. Y.
GURLEY
The Gurley Shaft Position Encoder

MIL-E-5272A. It has a rotor moment of inertia of 1.15 gm cm², weighs 3.1 oz, and is housed in a passivated stainless steel case. Its two-phase motor draws 3 watts per phase and provides 0.3 oz-in. of torque at stall. No load speed is 6,500 rpm. Generator output is 0.25 volt per 1,000 rpm, linearity within ½ percent, and phase shift plus or minus 10 deg.–John Oster Mfg. Co., Racine, Wis.

Circle No. 236 on reply card

ACCESSORIES & MATERIALS



SPACE SAVER

The HP610100 Servo Panel Package includes a solenoid-operated selector valve, a metallic mesh filter with differential pressure indicator, a system relief valve, gage snubber, and ports for pressure, auxiliary system, and return. Built for 3,000-psi operation, the unit not only reduces the space requirement but also cuts assembly time by eliminating many line and fitting connections.–Hydra-Power Corp., New Rochelle, N. Y.

Circle No. 237 on reply card

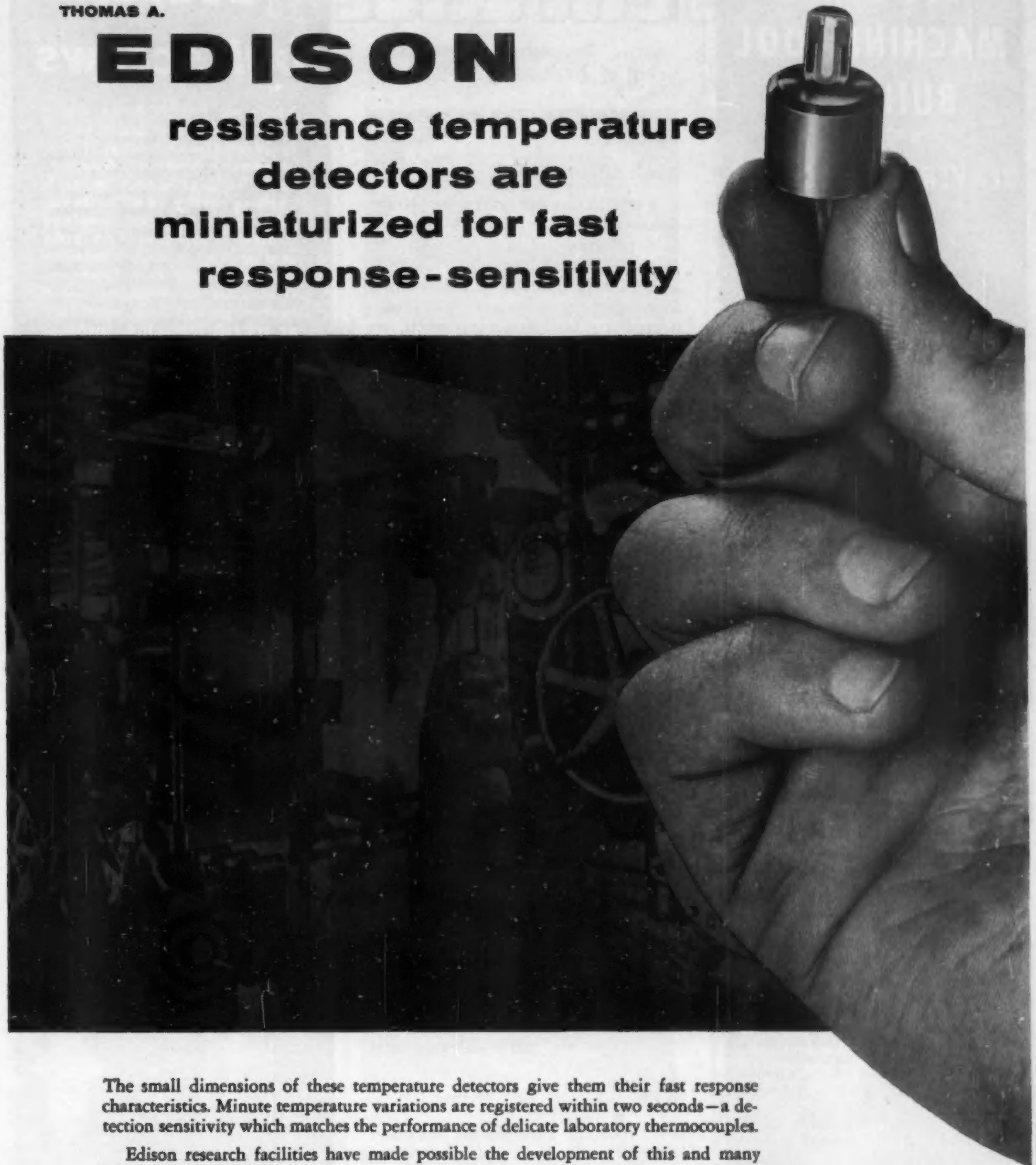
ADDED PROTECTION

Gage Gard Jr., a low-pressure-range protective device, seals off sensitive pressure measuring equipment at 2 percent below nominal cutoff point. Fully adjustable, this cutoff point may be set by an operator or, if desired, set and sealed at the factory. Maximum pressure after cutoff is 300 psi. Applications include the protection of inclined manometers, draft gages, electrical pressure switches, and ultra-

THOMAS A.

EDISON

resistance temperature detectors are miniaturized for fast response-sensitivity



The small dimensions of these temperature detectors give them their fast response characteristics. Minute temperature variations are registered within two seconds—a detection sensitivity which matches the performance of delicate laboratory thermocouples.

Edison research facilities have made possible the development of this and many other special purpose detectors to new engineering standards.

Designed to measure oil film temperatures, these units have been miniaturized to the point where they can be positioned in direct contact with bearing oil film in a wide variety of applications.

For complete information on Edison Resistance Temperature Detectors, write for Bulletin No. 3016.

Thomas A. Edison Industries
INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.

sensitive low-pressure transducers.—Industrial Engineering Corp., Louisville, Ky.

Circle No. 238 on reply card

REDUCES PICKUP

A new flexible cable with a four-strand figure-eight weave reduces magnetic field radiation by more than 20 db. Presently available in No. 24 wire size, it is particularly suited for low-frequency applications such as interconnecting shielded components, input systems with exposed cable lead-ins, and filament strings in high gain systems. Considerable space may be saved, because normally no further shielding is required. — Magnetic Shield Div., Perfection Mica Co., Chicago, Ill.

Circle No. 239 on reply card

ONE-PIECE COUPLING

This five-times enlargement illustrates the one-piece construction of a new miniature shaft coupling. One model, now in production, measures $\frac{1}{4}$ in. in diameter by $\frac{1}{4}$ in. in length and is bored to accommodate $\frac{1}{8}$-in. shafts. Ground from a single solid piece of material, these couplings assure smooth bearing loads, constant velocity, and zero backlash.—Helical Products Co., Hermosa Beach, Calif.

Circle No. 240 on reply card

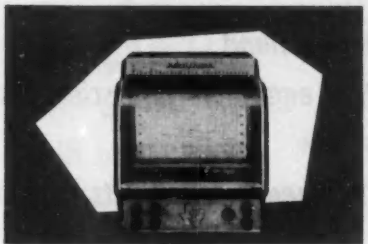
PLUS . . .

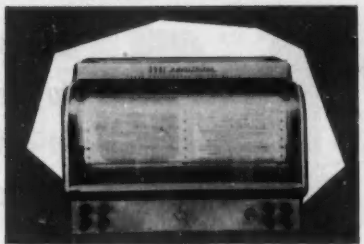
(241) **Marotta Valve Corp.**, Boonton, N. J., recently developed a new **pressure reducer** for programming pressure systems in the 50-to-6,000-psig range. . . . (242) **Bowman Instrument Corp.**, Fort Wayne, Ind., offers a new concentric-shaft **speed reducer** with a 30-min maximum backlash. . . . (243) **Purge valves** for bleeding gases or liquids from instrument or process lines are available for stock delivery from **Nuclear Products Co.**, Cleveland, O.

Circle No. 241, 242, or 243 on reply card

What's your application for versatile recti/riter® recorders?

TI's Applications Engineering Department invites your requests for technical assistance in OEM or end uses. Here are a few of the present applications.

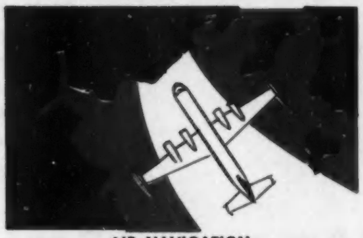




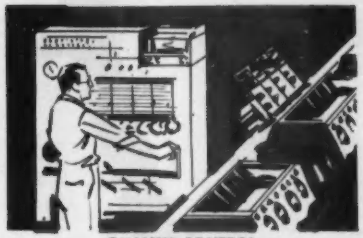
SINGLE and **DUAL**
Rectilinear Galvanometric Recorders, with a wide choice of sensitivities and "recti/riter" accessories, offer the most complete ranges available for recording electrical parameters from many types of transducers.

MISSILE TESTING
—a bank of "recti/riter" units record voltage frequencies and currents.

MEDICAL RESEARCH
—used with rate meters and nuclear scanners . . . also used to monitor rate of impurities in vaccines.



AIR NAVIGATION
—used to monitor ILS beams . . . also used to monitor LORAN signals.



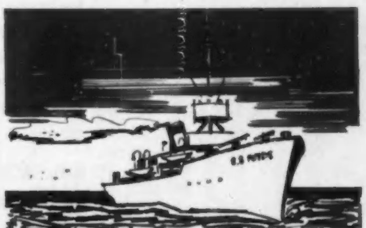
QUALITY CONTROL
—used on numerous production lines to check sizes and contours of parts, as well as assembly rates.

METEOROLOGICAL
—records wind directions and velocities . . . also used in studies of Aurora and air glow through scintillometer counters.

AUTOMATIC COMPUTERS
—for studying stability of electrical parameters that affect accuracy.

OIL EXPLORATION
—used in well logging as well as airborne magnetometers and scintillometers.

RADAR SPEED METERS
—used in police vehicles to visually record speed of passing motorists.



OCEANOGRAPHY
—records wave frequency and magnitude . . . also monitors underwater pressures.

ATOMIC TESTING
— used to measure radiation fall-out at test centers and nuclear installations.

TI will custom manufacture "recti/riter" recorders to your specifications for OEM use. Write for complete information.

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IMPORTANT: Circle key numbers below and mail before March 1, 1959

One of these handy prepaid post cards will bring you detailed information

IMPORTANT: Circle key numbers below and mail before March 1, 1959

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
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9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
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205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

Name ____________________ Title ____________________

Company ____________________

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209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

Name ____________________ Title ____________________

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BUSINESS REPLY MAIL
First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 1 (1-59)

CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

INSTRUCTIONS

Use these reader service cards to get more information on advertised products, new product items or catalogs and bulletins appearing in Control Engineering

Postage Will be Paid by Addressee

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BUSINESS REPLY MAIL
First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 2 (1-59)

CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

1.

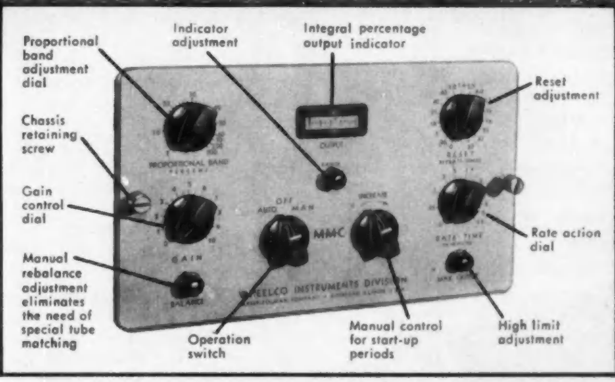
Circle number on card that coincides with key number listed at bottom or adjacent to item of interest.

2.

Fill in your name, title, company and address.

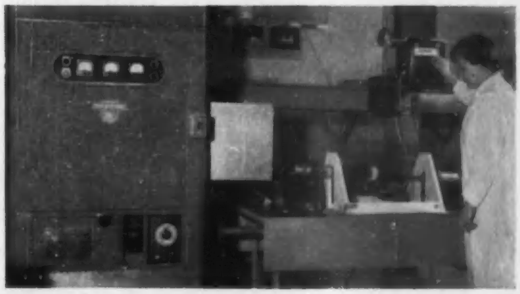
3.

Mail card immediately.



The 3-function controller for automatic rate, reset and proportioning action on a millivoltmeter-type controller is a Wheelco exclusive. It provides outstanding process control accuracy at minimum cost.

Harsh thermal shocks must be avoided in this induction heating setup for growth of germanium semi-conductor crystals. Growth is in Vycor tube with heating coil on outside and carbon ring holding thermo-couple inside.



BARBER-COLMAN COMPANY

Dept. M, 1348 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. M, Toronto EXPORT AGENT – AD. AURIEMA, INC., NEW YORK

Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Small Motors
Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

CIRCLE 93 ON READER-SERVICE CARD

BULLETINS AND CATALOGS

NOTE: This month's Bulletins & Catalogs section starts with several items for which the reader must submit written requests. Complete addresses are given for these items.

AIDS BREADBOARD DESIGN. PIC Design Corp., 477 Atlantic Ave., East Rockaway, L. I., N. Y. This offer consists of a complete package of over 14 design tracing templates, created to assist designers, engineers, and others associated with the development of specific mechanical systems. They can be used for breadboard layouts, prototype design, technical sketching, and detail drawings.

MAGNETIC AMPLIFIERS. Electric Products Div., Vickers, Inc., 1815 Locust St., St. Louis 3, Mo. A 36-page illustrated bulletin covers the basic principles, operating characteristics, and typical applications of magnetic amplifiers. Cutaway drawings and exploded views show design details, performance curves illustrate output characteristics and frequency response. Ask for Bulletin 1105-1.

SERVOVALVES. Moog Valve Co., Inc., Proner Airport, East Aurora, N. Y. Catalog 210 contains characteristic curves and schematics that highlight the performance and design of Moog's low-flow servovalves for military, industrial, and research applications. Also features a short glossary of servovalve terms.

SERVO TEST GEAR. Theta Instrument Corp., 48 Pine St., East Paterson, N. J. This 42-page spiral-bound booklet describes in detail the theory and application of synchro and resolver testing techniques. Authors explain these somewhat complicated tests by reference to the measurements and equipment involved.

(300) DIGITAL RECORDER. Fischer & Porter Co. Catalog 35A1000, 16 pp. Well-illustrated bulletin covers the standard and optional features of a new punched-tape digital demand recorder. Describes the operation and design features of each individual component, and lists significant specifications.

(301) YIELD DETERMINATION. Nuclear-Chicago Corp. Technical Bulletin No. 1, 4 pp. Details the application of radioisotopes to the problem of yield determination in quantitative analyses, outlines proper procedures, and answers common questions about use.

(302) ALL ABOUT DRAFT. The Hays Corp. Bulletin No. 58-S201, 20 pp. Answers the What, Where, How, and Why of draft as it affects the efficiency of the combustion process, and provides full details on various types of draft gages for measuring low and differential pressures.

(303) HYDRAULIC PANELS. Petch Mfg. Co. Bulletin H-58, 8 pp. Covers a new hydraulic fabrication technique that uses building-block standard component subplates with pressure, return, and drain lines manifold within the block. Photos, isometrics, and dimension drawings amplify the text.

(304) DIGITAL VOLTMETER. KinTel

Div., Cohu Electronics, Inc. Data Sheet No. 19-24, 2 pp. Offers an interesting description of the circuit used in the company's Model 402 ac/dc Digital Voltmeter, and complete specifications.

(305) SYNCHRONOUS MOTORS. Electric Indicator Co., Inc. Catalog EI-4, 28 pp. Includes extensive detailed data on over 200 representative Elinco synchronous motor designs, giving particular emphasis to a wide selection of hysteresis motors. Convenient reference tables provide detailed specifications on the electrical, physical, and performance characteristics of each motor type.

(306) MAGNETIC SHIELDING. Magnetic Shield Div., Perfection Mica Co. Manual No. 101-122. 31 pp. Describes design and fabricating techniques for nonshock sensitive, nonretentive Netic and Co-Netic magnetic shielding in standard gages and thin ducile foil; 40 illustrations depict a wide variety of shapes, sizes and applications.

(307) MECHANICAL STOPS. Kearfott Co., Inc. Advance Technical Data K1480-10, 2 pp. Offers reference data on a new line of Size 10 precision mechanical stops for 1 to 30 revolutions. Application formulas will aid the user in determining inertias and torques.

(308) HYDRAULICS APPLIED. The Oilgear Co. Fluid Power News No. 8, 4 pp. Lead article tells how Oilgear "Any-Speed" drives accurately control section speeds on a 264-in. paper machine. Another paper-mill application story covers the modernization of a laminator.

(309) TUBELESS CONTROLS. Autotran, Inc. Catalog 58-1, 4 pp. Describes a complete line of tubeless photoelectric controls, featuring both self-contained and remote sensing heads. Illustrations include photos and dimensional diagrams.

(310) HYDRAULIC PUMP. Waldorf Instrument Co. Data Sheet WF1642, 2 pp. Lists specifications, and illustrates four typical applications, of the Model 120-1 self-contained reciprocating pump.

(311) SOLENOID VALVES. Waterman Engineering Co. Catalog No. 2000, 12 pp. Provides complete details on a line of two- and three-way ac and dc solenoid valves. Pressure drop charts and dimension drawings accompany the descriptions.

(312) PHOTO-TAPE SYSTEMS. Datasyne Div., Berndt-Bach, Inc. "Catalog of Ideas", 40 pp. Well-illustrated booklet discusses a versatile new data recording system which combines electronic tape recording with motion picture photography. A question and answer section covers many of the technical details.

(313) POWER SUPPLIES. Perkin Engineering Corp. Catalog E 59, 12 pp. Products covered include a wide variety of dc power supplies, ac line-voltage regulators, and inverters for both military and commercial applications.

(314) PULSE TRANSFORMERS. Technitrol Engineering Co. Technical bulletin, 2 pp. Summarizes electrical and environmental specifications on miniature encapsulated pulse transformers. Dimension drawings illustrate different case styles.

(315) BALL SCREWS. Beaver Precision

HOW SMALL

CAN PRECISION COMPONENTS BE?

Synchros and associated components now can be small enough and light enough for use in many crucial assignments where size and weight must be minimal. Ketay has led the way in miniaturization without sacrifice of performance and environmental resistance.

Ketay's size 8 components meet and surpass current MIL design objectives. They are available in production quantities to meet strict delivery schedules.

Notable examples of Ketay competence in miniaturization include:

Size 8 synchros—only Ketay offers a complete line including high impedance units. Exclusive construction features—as well as stainless steel housing and materials of matched temperature coefficients—help assure high accuracy over a wide temperature range and resistance to corrosion and deformation.

Size 8 servo amplifiers—only Ketay offers transistorized 0.8 cubic inch units which deliver 2 watts output continuously from —55° to 100° C without a heat sink; 200 to 1000 volt normal gains can be supplied.

Size 8 servo motors—Ketay offers units of outstanding high ratio of stall torque to power input (0.25 oz. in. for 3.4 watt input at 6500 rpm), center-tapped for transistorized applications.

Ketay engineers are regularly working on advanced new components and prototype control systems. Call or write for help in solving your special problems.

Ketay precision components:

SYNCHROS
RESOLVERS
POTENTIOMETERS
SERVO MOTORS
TACHOMETERS
SERVO AMPLIFIERS
GYROMECHANISMS

Catalogues available.

NORDEN DIVISION of United Aircraft Corporation

KETAY DEPARTMENT, Commack, Long Island, N.Y.

CIRCLE 96 ON READER-SERVICE CARD

Products, Inc. Catalog, 8 pp. Presents both design and application data on ball screws, ball splines and ball ways. Includes a load-deflection plot, table of dimensions, and discussion of critical speed.

(316) VARIABLE SPEED DRIVE. Humphrey, Inc. Bulletin No. S-101, 2 pp. Four drawings illustrate a few of the many applications for a new mechanical variable speed drive. Dimension drawings, characteristic curves, and a specification list complete the coverage.

(317) TEMPERATURE MONITORS. Thomas A. Edison Industries. Publication No. 3036C, 32 pp. Actually consists of two bulletins and five two-page data sheets covering a complete line of temperature detectors, indicators, and monitors.

(318) VIBRATING CAPACITORS. Stevens-Arnold, Inc. Catalog 523-A, 4 pp. Circuit diagrams illustrate some typical applications of a new component for measuring extremely low currents. Describes an economy-model for less exacting work.

(319) ALL ABOUT SOUND. H. H. Scott, Inc. This 8½ by 11 booklet, entitled "Noise Simplified", provides a lot of information on the instrumentation, measurement, analysis, and control of sound.

(320) UNIVAC APPLICATION. Remington-Rand Div., Sperry Rand Corp. Brochure U-1560, 16 pp. "Harmonic Analysis With the Univac 120 Punched-Card Electronic Computer" is the title of this one. It describes specific procedures for tabulating empirical data and analyzing periodic functions.

(321) ADJUSTABLE SPEED DRIVES. Louis Allis Co. Bulletin 2750, 6 pp. Contains a two-color cutaway drawing of one of the company's Adjusto-Spede Drives and points out its salient features. Covers specifications, controls, and wiring.

(322) CONTROLS CATALOG. Barber-Colman Co. Automatic Controls Catalog No. 26, 52 pp. Describes and illustrates a complete line of automatic controls for heating, ventilating, and air conditioning systems. Products include thermostats, pressure controls, motor-operated valves, temperature regulators, and many others. Application data with each description.

(323) THERMOCOUPLE DATA. Thermo Electric Co., Inc. Catalog, 12 pp. (Section E) A complete roundup of the company's heavy-duty industrial thermocouple assemblies. Includes thermocouples, wells, connection heads, and fittings. Illustrated index simplifies composition of complete assemblies.

(324) FORCED AIR COOLING. McLean Engineering Laboratories. Technical article, 6 pp. This reprint from "Electronic Design" supplies engineering information on thermal design of electronic equipment and surveys available cooling methods. Tables and charts furnish performance and application data.

(325) HANDY NOMOGRAPH. Milton Roy Co. 11x17 in. nomograph. Easy-to-use design aid simplifies sizing of controlled-volume pumps and tanks for chemical feed systems. Enables chemical engineers to calculate correct sizes in a matter of a few seconds.

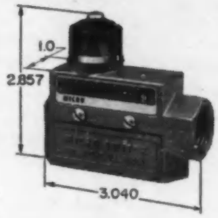
(326) PRECISION TACHOMETERS.

MICRO SWITCH Precision Switches

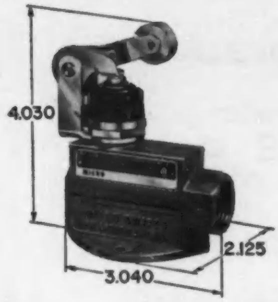
New "E6" and "V6" Enclosed Switches available in 6 actuator designs

With new ease of installation, improved insulation and sealing, heavier wall sections without change of envelope dimensions, these new switches are interchangeable with our "E" and "V" designs.

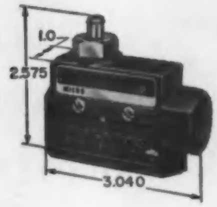
Available in six integral actuator designs to meet most precision switch requirements. All six are available in either side mounting (E6) or bottom mounting (V6) style.



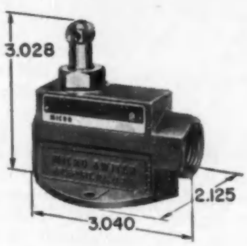
Plunger actuator for straight, in-line operating motion with controlled overtravel. Elastomer actuator boot protects against dirt and moisture.



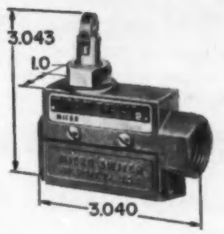
Roller lever actuator for cam or slide motion, adjustable horizontally through 360°, vertically through 225°. Elastomer actuator boot.



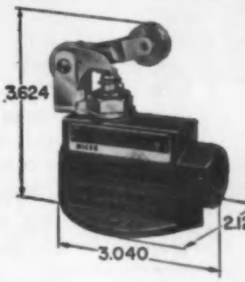
Plunger actuator for straight, in-line operating motion with controlled overtravel.



Roller plunger actuator for slow-rise cam or slide motion with controlled overtravel. Roller in line with case.



Roller plunger actuator for cam or slide motion with controlled overtravel. Roller at 90° angle to case.



Roller lever actuator for cam or slide motion, adjustable horizontally through 360°, vertically through 225°

New switch design lets terminal screws project from top portion of the housing. Wiring is easy. Gasket and insulator are one-piece, cemented to bottom housing . . . fewer parts, no separate gasket. The new elastomer insulator-seal provides better insulation and a tighter long-life seal. New housings have thicker walls and greater strength, yet have same outside dimensions and same mounting holes as "E" and "V" switches. New hex-shaped (instead of round) conduit hub greatly facilitates tightening conduit connection. Basic switch is replaceable in all cases.
Send for Catalog 83.

MICRO SWITCH . . . FREEPORT, ILL.
A division of Honeywell
In Canada: Honeywell Controls, Ltd., Toronto 17, Ontario

Honeywell
MICRO SWITCH PRECISION SWITCHES

Kearfott Co., Inc. Brochure, 12 pp. Consists of four two-page data sheets on individual servomotor-generators and tachometer-generators, within a four-page folder that presents general performance characteristics. Latter is loaded with curves and circuit diagrams.

(327) PANCAKE MOTORS. Louis Allis Co. Bulletin No. 2100, 4 pp. Emphasizes construction and performance characteristics of a new line of enclosed pancake motors. Cutaway drawing shows how formed-end coils and a one-piece housing bearing bracket permit a 60-percent reduction in length.

(328) PIPELINE SAMPLING. B-I-F Industries, Inc. Technical Bulletin SM 9475-2, 8 pp. Photos and schematic drawings illustrate this discussion of such technical aspects of pipeline sampling as line stratification, flow profile, sample probe location, and economic factors.

(329) THE CHOPPER. The Airpax Products Co. Parts I and II (two booklets) in a series on "The Contact Modulator", 24 pp. each. First booklet answers the question, "Why use choppers?" and the second covers "Definitions and Measurements". Both have been prepared by the company's engineering staff and should be excellent reference material. First book also contains a short glossary of chopper and amplifier terms.

(330) DIGITAL VOLT-OHMMETER. Franklin Electronics, Inc. Bulletin 400A, 4 pp. Treats a test instrument that measures dc, from 0.01 to 1,000 volts, positive or negative, to an accuracy of 1.5 percent; ac, from 0.01 to 1,000 volts up to 100 kc, to an accuracy of 2 percent, and resistance, from 10 ohms to 1 megohm, to an accuracy of 2.5 percent.

(331) CONTROL VALVES. Conoflow Corp. Bulletin LB-3, 12 pp. The new series LB, says the literature, features a single-seated body and a rugged metal-piston cylinder actuator, integrated to eliminate the conventional diaphragm. Sections of this big, clear presentation include construction features, optional accessories, flow formulas for sizing, and a few paragraphs on tight shutoff.

(332) LEVEL CONTROL. Syntron Co. Data Sheet, one page. Describes the Syntron diaphragm hopper level switches for automatically maintaining accurate minimum-maximum levels of materials in bins and hoppers. Illustrates operation and suggests applications.

(333) DAMPING WITH GAS. Statham Instruments, Inc. Instrument Notes 33, 4 pp. Entitled "Some Characteristics of Gas Damped Accelerometers", these instrument notes outline the concept of gas as the damping medium for dynamic measuring devices, explain how its relative insensitivity to temperature change gives it an advantage over oil damping.

(334) ANNUNCIATORS. Scam Instrument Corp. Bulletin 1058, 6 pp. Tells about static-switching monitoring circuits that have no moving parts, and consequently cannot be affected by climatic conditions. The eight Scammit models shown range from single and multiple units, both large and miniature, to common horn relays.

Continued from page 46

annual figures—$10,235,155 in net sales and $911,139 in net earnings for the fiscal year ending Oct. 31, 1957—testify to its successful efforts to strike out on its own.

• **More jobs for bearings**—After the Korean war, Barden concentrated on precision bearings for gyros, synchros, and servo components. Today, in its new home—and in two other plant locations in Danbury—it is probing applications in which bearings for high speeds and high temperatures can be used in machine-tool spindles, dental drills, computing machines, and small turbine engines.

Complete mechanization of inspection is not yet a reality, though Barden has built some completely automatic inspection apparatus and the instrumentation for its visual inspection steps is extensive. Example: the Barden Smoothrator is a final-inspection device that can measure the nonuniformity of a bearing as it slows from a spin.

• **Work bears fruit**—Recent results of its development work include: a dynamic bearing assembly—a virtually torque-free support for gyro gimbals—in which an electromagnetic vibrator driven by a transistorized oscillator "dithers" the outer race of a double-race bearing to reduce friction by 30 to 1; and the Nysorb ball retainer, which reduces oil mass shift in gyro rotor bearings. Other work covers synchro bearings for 1,100 deg F with Pyro-Ceram races (Pyro-Ceram is a Corning Glass product) and extra-precise bearings with inner and outer diameters lapped to within ½ micron.

Other control engineering companies followed Barden to Danbury. Of the eight listed in the table, five have their home offices in Danbury, one has a major division there and two have important plants. **—Warren Kayes**

COMPANY	THUMBNAIL HISTORY	IMPORTANT PROJECTS OR PRODUCTS
The Barden Corp.	Founded in Danbury in 1942; sparked by postwar need for precision ball bearings, of the type used in the bombsight produced by former parent Carl L. Norden, Inc. Had 200 employees when formed, has 1,000 today.	The dynamic bearing — see text.
Data-Control Systems, Inc.	Formed in Danbury in 1957 by a group headed by former ISA President Robert J. Jeffries; has made great strides due to Jeffries' organizational ability, and to the engineering ability of such staffers as Raymond A. Runyan, head of telemetry development. Grew from four employees to 250 in a year.	Some new solid-state units: a voltage controller less than 4 cu in.; an all-electronic commutator less than 20 cu in., able to sample 900 bits per sec; an electronic oscillator.
Consolidated Controls Corp.	Formed in 1958 by Consolidated Diesel Electric Corp., to acquire the Aircraft Products Div. of Manning, Maxwell & Moore. Had 130 employees when it opened, has 170 today.	Instrumentation for nuclear-powered submarines — a Westinghouse contract.
Danbury-Knudson Div. of Amphenol Electronics Corp.	Formed in 1919 as Danbury Electric Mfg. Co., name changed to Danbury-Knudson in 1934. In 1957, Danbury-Knudson and its Industrial Products Co. Div. became separate divisions of Amphenol Electronics. D-K Div. employs 130, IPC 150.	Connectors and electronic specialties, including coaxial relays and microwave components for telephones; RF connectors.
Manning, Maxwell & Moore, Inc.—Industrial Controls Div.	Parent company one of the oldest in Connecticut. One component, Ashcroft Mfg. Co., was formed in 1850; partnership of Manning, Maxwell & Moore, which purchased Ashcroft, was itself formed in 1880. MM&M moved its Industrial Controls Div. to Danbury in 1958, into the plant vacated by its Aircraft Products Div. (see Consolidated Controls Corp.)	The Microsen line of dc electronic process control instruments, first introduced in 1952. Systems incorporating these instruments measure, transmit, record, and control in the process industries, in flight test installations, and in atomic reactors.
The Perkin-Elmer Corp. — a plant for its Engineering & Optical Div.	In 1957, attracted to this 16,000-sq-ft machine shop by the presence there of a full staff of machinists, Perkin-Elmer took out a five-year lease. Today, plant employs 66, consisting of machinists, quality control people, and a small management staff.	The mechanical portion of alignment theodolites, used for "squaring up" inertial guidance systems.
Reeves Soundcraft Corp.	Founded in New York City in 1946 to exploit the opportunities in manufacture of recording discs. Entered magnetic tape business in 1950, moved to Danbury in 1958. Opened for business with 20 employees, has 200 today.	Magnetic tape, particularly instrumentation tape for data processing machines, programming, and for missiles and satellites.
Sperry Products, Inc.	Founded by Elmer A. Sperry in 1926 as Sperry Development Corp., moved from New York City to Hoboken, N.J., in 1938, and to Danbury in 1948. Sperry envisioned a company devoted to independent research and the pursuit of new objectives; Sperry Products believes it lives up to this dream. Employs 450.	Standardization of two basic product lines: mobile radio, and equipment for automatic assembly and machining. Sperry's transistorized radio line for railroads is creating considerable interest.

WHAT'S NEW

work in the fields of the future at NAA

Minneapolis Memo:

Will anything develop between Control Data Corp. and the new investment company headed by CD's former vice-president?

MINNEAPOLIS—

A new investment company, similar in intent to the type just recently approved by the Small Business Administration (CtE, Dec., p. 120), has been formed here by a group of local businessmen, two of them former executives of Control Data Corp. One of the two, Arnold J. Ryden, who had been Control Data's vice-president and treasurer and is now president of the new Midwest Technical Development Corp., would make it clear that:

- There is no connection between his new company and Control Data, though he remains a director and a consultant of the latter firm; nor is there any financial interest.
- Control Data's $144,716 loss in its first year (CtE, Nov., p. 168) had nothing to do with his departure, nor with the departure of Willis K. Drake, director of marketing, who has been named a vice-president of the new company. In fact: "Control Data currently is operating in the black, it has a good backlog, and the operation is very sound." Proof, says Ryden, is the successful negotiation of a $350,000 preferred stock placement with Allstate Insurance Co. (CtE, Dec., p. 120).
- Midwest Technical is simply a regulated, closed-end investment company of the kind provided for by the Investment Act of 1940. However, says Ryden, his group may set up another, smaller company under the new Small Business Investment Act of 1958 (the type described last month), after he and his associates have had a chance to study the regulations.
- Though it is true that Remington Rand Univac is a favorite personnel source of Control Data*, there is nothing to be read into Midwest Technical's hiring of Byron D. Smith, formerly chief engineer for product planning at Univac, as a vice-president.

Midwest Technical plans to raise an initial $1.5 million through the sale of common stock, then "invest in small, successful technical com-

* Most recent acquisitions: Kenneth E. Johnson, Charles T. Casale, and James D. Johnson, senior electronic computer engineers, all formerly with Univac. But Control Data has gone elsewhere, too. One result: Robert E. Smith, formerly head of the Dept. of Mathematics of Duquesne University, named senior mathematician.

panies whose potential can be increased by adding capital". A wholly-owned subsidiary, Technical Management Services Corp., will consult with these companies on finance, product planning, and marketing.

Amphenol Plans Merger with George W. Borg Corp.

The managements of Amphenol Electronics Corp. and The George W. Borg Corp. have agreed to merge. The plan, which was to have been approved by stockholders last month, would bring together organizations with total assets of more than $37 million and capable of generating more than $50 million a year in sales. Arthur J. Schmitt, president of Amphenol, would be chief executive officer.

Now It's: Snyder Corp., Bradley Semiconductor Corp.; 2 Divisions Also Renamed

Recent name changes to bring the name more in line with the products made or to avoid any misconceptions about them, include:

- Snyder Corp., from Snyder Tool & Engineering Co., a machine tool builder that has successfully diversified operations with the Arthur Colton Co. Acquired by Snyder in 1949, Colton is having its best business period despite the recession, which has been particularly unkind to the machine tool industry. (Colton makes machinery for the pharmaceutical and packaging industries.)
- Bradley Semiconductor Corp., from Bradley Laboratories, Inc., maker of current rectifiers, diodes, modulators, and arc suppressors.
- The Electro Mechanical Instrument Div. of Consolidated Electrodynamics Corp., division name changed from Central Manufacturing Div. The unit produces dynamic-recording and data-processing instruments and auxiliary equipment. Its director is A. P. Stuhrman.
- The Control Instrument Div. of Warner & Swasey Co. In this case, W&S has not only changed the name of its Warner & Swasey Research Corp., but has also altered its status: from subsidiary to division. The division manufactures the Probograph, which measures curved surfaces; and the Probomat, which controls machine tools via tape. In the works is the Imrapyrometer, which measures the temperature of hot gases.

WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

R. D. Clark Chief Engineer of Clary Dynamics Div.

Robert Duff Clark, formerly a missile design specialist with Convair, has been appointed chief engineer for Clary Dynamics Div. of the Clary Corp. Clark has also been chief engineer for Page Oil Tools, Inc.

Ernst Weber Succeeds Fink as IRE President

Ernst Weber, president of the Polytechnic Institute of Brooklyn and of Polytechnic Research & Development Corp., and guiding light of the Microwave Research Institute, is the new president of IRE. He succeeds Donald G. Fink, director of research for Philco Corp. Educated in Austria and Germany, where he received his early training, Weber came to this country in 1930 as visiting professor at Brooklyn Poly. He became president of the institute last year.

Elected to serve with Weber were Donald B. Sinclair, vice-president and chief engineer of General Radio Co., West Concord, Mass., vice-president; and Ferdinand Hamburger Jr., professor of EE at The Johns Hopkins University, and Bernard M. Oliver, vice-president for R&D, Hewlett-Packard Co., directors.

Other Important Moves

The Convair Astronautics Div. of General Dynamics Corp. has named **Frank J. Dore,** formerly project engineer for special projects, chief of systems analysis.

The new chief of systems design in the Electronics Div. of Curtiss-Wright Corp. is **T. Courtenay Wakefield,** who has been with C-W since 1942, most recently in positions connected with missile development and engine analysis for flight simulators.

Arthur W. Vance, most recently chief engineer of RCA's Astro-Electronic Products Div., has been named head of Hughes Aircraft's new Information Processing Research Dept. He was with RCA for nearly 30 years.

As manager of engineering for the Helipot Div. of Beckman Instruments, Inc., **Stanley Schneider** will direct design, development, and modification of potentiometers and power monitoring equipment. His most recent position was chief research engineer.

Automatic Landings a Must

From "Automatic Flare Systems for Aircraft, Missiles, and Space Vehicles" by E. R. Buxton, Autonetics Div. of North American Aviation, Inc. Paper presented at the SAE National Aeronautics Meeting, Los Angeles, Calif., Oct. 2, 1958.

This report reviews the fundamentals of the automatic landing problem, presents certain solutions and test results, and introduces some new concepts that promise improved systems for the future.

The completely automatic air vehicle recovery system offers considerable economic advantages in both commercial and military applications. In the case of commercial carriers, for example, it could save a large part of the $6 million in revenue annually lost because of bad weather within 200 ft of the ground. In manned air-breathing weapon systems, an automatic recovery system would, in addition to providing all-weather capability, minimize fuel consumption and thereby increase the range.

Perhaps the most important requirement of any automatic landing system is that it perform at least as well as the human pilot, and with perfect reliability. If it does not do this, its chances of acceptance are nil. To provide such performance, systems developed to date have used one of two servo techniques.

In one, the exponential flare method, sinking rate is held proportional to altitude so that $\dot{h} + Th = 0$ (where the time constant T has been found optimum at about 5 sec). The block diagram in Figure 1 illustrates this type of system and Figure 2 shows

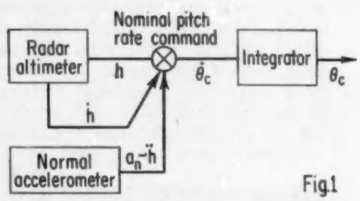
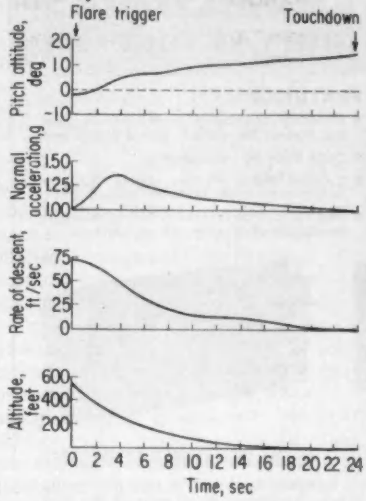


Fig.1

results obtained in the X-10 missile during flare from a 10-deg approach angle. Note the nearly constant pitch rate. This is attributed at least in part to the reduction of airspeed, which necessitates an increase in the angle of attack. Since altitude h, altitude rate $\dot{h}$, and normal acceleration $\ddot{h}$, all approach zero at touchdown, an open-loop bias is put into the flare path integrator. This not only eliminates

Fig. 2

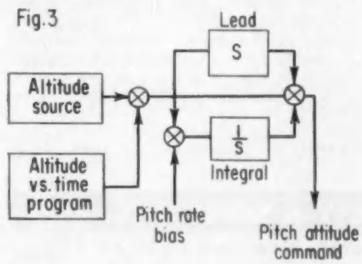


complex speed controls, but also permits speed bleed-off during flare. In a six-year test and utilization program, systems using this technique have accumulated, over 1,000 landings of F-86D, F-102, and X-10 vehicles.

The second technique tested to-date is the path program system, in which altitude is programmed as a function of time or range. Altitude error, rate of error, and integral of error are inserted as a pitch command into the autopilot. Stability restrictions prohibit tight path control with large speed variations, and open-cycle final pitch rate programming may be used. This is shown as a pitch rate bias in Figure 3.

Results obtained from tests of sys-

Fig. 3



tems using this technique appear to be quite similar to those obtained with the exponential flare method. Unfortunately, both techniques have one fundamental shortcoming: system response to gust disturbances is unnatural to pilot experience.

Although both techniques are safe from the standpoint of structural limitations, they fall short of winning the pilot's confidence. A third method, the predictor technique, comes a lot

closer in this respect. Here, the object is to bring the altitude to zero at an exact future time and rate of descent.

A system developed to provide this action is shown in Figure 4 and is

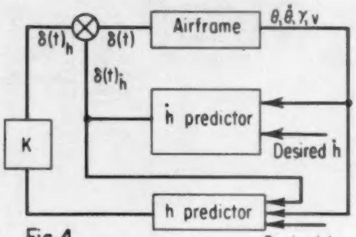


Fig.4

called a "terminal controller". It uses both an altitude predictor and an altitude rate predictor. The rate or inner loop predicts the control input needed to produce the desired sink rate at the time of touchdown. Outer-loop prediction is based on the inner-loop output and initial conditions that define altitude at the terminal time, assuming no control action. Computer studies and flight test results indicate that the predictor technique will find much wider acceptance than the others.

Parts of a Bibliography

From "Classified Bibliography on Feedback Control Systems", Parts I and II. AIEE Conference Papers 58-1269 and 58-1270, presented at the AIEE Fall General Meeting, Pittsburgh, Pa., Oct. 26-31, 1958.

These papers represent the first two parts of an exhaustive 15-part classified bibliography on automatic feedback control systems theory, intended to complement, supplement, and update earlier AIEE, IRE, and British bibliographies.

In Part I, Prof. T. J. Higgins of the University of Wisconsin and R. W. Greer of North American Aviation Corp. list over 250 references on the subject of sampled-data systems. Listings are in chronological order and range from a 1934 entry in the *Journal of the Franklin Institute* to a McGraw-Hill book slated for publication early this year.

Part II, also by Professor Higgins, covers the subject of root locus and associated proceedures. Its 79 entries span a period of about 10 years, beginning with a 1948 AIEE Transactions paper by W. R. Evans on the graphical analysis of control systems. In both Part I and Part II the listings for any one year are further arranged alphabetically by authors.

NEW BOOKS

Emphasis on Analogies

ENGINEERING SYSTEMS ANALYSIS. *Robert L. Sutherland, Iowa State University. 223 pp. Published by Addison-Wesley Publishing Co., Reading, Mass., 1958. $7.50.*

The value of this book lies not so much in the material it covers as in the manner in which it ties this material together. Others have covered the same subject matter—mechanical vibrations, electrical oscillations, dynamical systems, dimensional analysis, feedback theory, and analog and digital computing machines. Very few of these authors, however, cover all these subjects in a single book, aimed primarily at satisfying the needs of the undergraduate engineering student. Even more important than this breadth of coverage is the emphasis Sutherland places on the analogies that exist between systems in entirely different fields of engineering. These analogies exist in the mathematical expressions for the various systems, and an understanding of them is a valuable asset to the young graduate and particularly the would-be control engineer.

As a text for an undergraduate elective in engineering analysis, the book should prove an excellent choice. The author's clear, step-by-step approach to each subject and his successful efforts in tying them together make the book suitable also for home study.

Cites Practical Applications

SAMPLE DATA CONTROL SYSTEMS. *J. R. Ragazzini and G. F. Franklin. 331 pp. Published by the McGraw-Hill Book Co., Inc., New York, 1958. $9.50.*

A number of articles have appeared in the IRE Proceedings on various parts of sampled data theory. Truxal too, in his book on control system synthesis, has included sections on the elements of sampling theory. This book, however, is devoted entirely to the subject, and in this respect may be a "first". The authors do an excellent job of presentation.

Starting with the elements of the sampling process and establishing the nature of the z-transform, the book moves quickly into the application of this theory to practical systems. Cascaded and closed loop z-transform transfer function relationships are derived and clearly illustrated with examples. An attempt is made throughout to show how Laplace transform techniques and other tools of the control

engineer can be extended to sampled-data control systems.

Going beyond the simple theory, the book covers such new and interesting topics as the use of digital computers in control systems, output waveforms between sampling instants, multirange sampling, random inputs, solution of difference equations, etc. The chapter on random inputs will be helpful to engineers in fields such as radar and nuclear instrumentation, where the signals are frequently of a random statistical nature.

The authors clearly explain the use of the z-transform as an aid in applying numerical analysis to everyday engineering problems. A good grounding in conventional Laplace transform and control system theory is helpful (if not necessary) to the reader, since the book is written in the standard terminology of the control engineer.

Unfortunately, the authors did not see fit to include a few problems at the end of each chapter; but the examples in the text partially compensate for this. Illustrations are well done and the book is quite free of printing errors. At least, they escaped this reviewer. It can be predicted that this book will be a standard reference for many years and as such is a welcome addition to the control engineer's library.

—Thomas J. Calvert

Metalcutting and Control

PROCEEDING OF THE EXPLORATORY CLINIC ON NEW INSTRUMENTATION REQUIREMENTS FOR METALCUTTING. *Edited by Lloyd E. Slater, Executive Director of the Foundation for Instrumentation Education & Research. 116 pp, 8½ x 11, paperbound. Published by FIER, Inc., New York, 1958. $5.*

The clinic that generated the nine papers contained in these proceedings was the third such meeting organized by the Foundation for Instrumentation Education & Research. Jointly sponsored by FIER, ASTE, and the University of Michigan, it explored the potential for new measurement and control techniques in the metalcutting industry.

The three papers presented during the second session are particularly interesting in that they are written by men outside the instrumentation field and pose an array of brand new problems for the control engineer. These papers outline the measurements required for a better grasp, of the metal-

cutting process, discuss present techniques for gathering this data, and constitute an open invitation to the control engineer to come up with some better ideas.

Analog Methods Applied

ANALOG SIMULATION—SOLUTION OF FIELD PROBLEMS. *Walter J. Karplus, PhD, Assistant Professor of Engineering, UCLA, 434 pp. Published by the McGraw-Hill Book Co., New York, 1958. $10.*

Fourth in the McGraw-Hill Series in Information Processing and Computers, this book provides a fairly comprehensive survey of analog techniques and systems for solving field problems.

Chapter 1, an introduction, opens with a general discussion of the basic characteristics of field problems; here the author carefully defines terms that will be used throughout the text. Advantages and disadvantages of the electric analog approach are described, and a few remarks made on the digital computer approach to the same problems.

Dr. Karplus then divides his subject into three major parts. Part 1 begins with a chapter on the mathematical principles and techniques for solving partial differential equations by electric analogs. Chapters 3 and 4 cover transformation methods and finite-difference approximations that apparently have not been treated before in texts on this subject.

The second part of the book, Chapters 5 through 10, deals with a variety of actual analog-simulation systems. These include conductive-solid analogs, conductive liquids, resistance networks, resistance-reactance networks, electronic analog computers, and nonelectric analog systems. Basic operation of each system is described in detail and useful auxiliary techniques outlined. The author continually points out advantages and limitations of the systems and carefully analyzes the possible sources of error.

Part 3, the last four chapters, illustrates applications of the mathematical techniques and systems described in Parts 1 and 2. Problems are categorized according to their mathematical form, and the general nature of each solution is stressed. The author does a good job of providing some physical insight into the relations between the elements of the analog system and the corresponding elements of the prototype system.

In addition to references at the end of each chapter, the book contains a 22-page chronological bibliography of over 500 technical papers.

WHAT'S AHEAD: MEETINGS

JANUARY

Institute of Radio Engineers, Fifth National Symposium on Reliability and Quality Control, Bellevue-Stratford Hotel, Philadelphia Jan. 12-14

FEBRUARY

Institute of Radio Engineers, 1959 Solid State Circuits Conference, University of Pennsylvania, Philadelphia Feb. 12-13

MARCH

Western Joint Computer Conference, Theme: New Horizons with Computer Technology, Fairmont Hotel, San Francisco March 3-5

Institute of Radio Engineers, 1959 National Convention & Exposition, Waldorf-Astoria Hotel and New York Coliseum, New York March 23-26

American Society of Mechanical Engineers, IRD Conference, sponsored by AIEE, IRE, ISA, and AIChE, Case Institute, Cleveland March 29-April 2

21st American Power Conference, sponsored by Illinois Tech, Hotel Sherman, Chicago. March 31-April 2

APRIL

International Atomic Exposition and Nuclear Congress, Public Auditorium, Cleveland April 5-10

Instrument Society of America, Second National Symposium on Chemical and Petroleum Instrumentation, St. Louis April 6-7

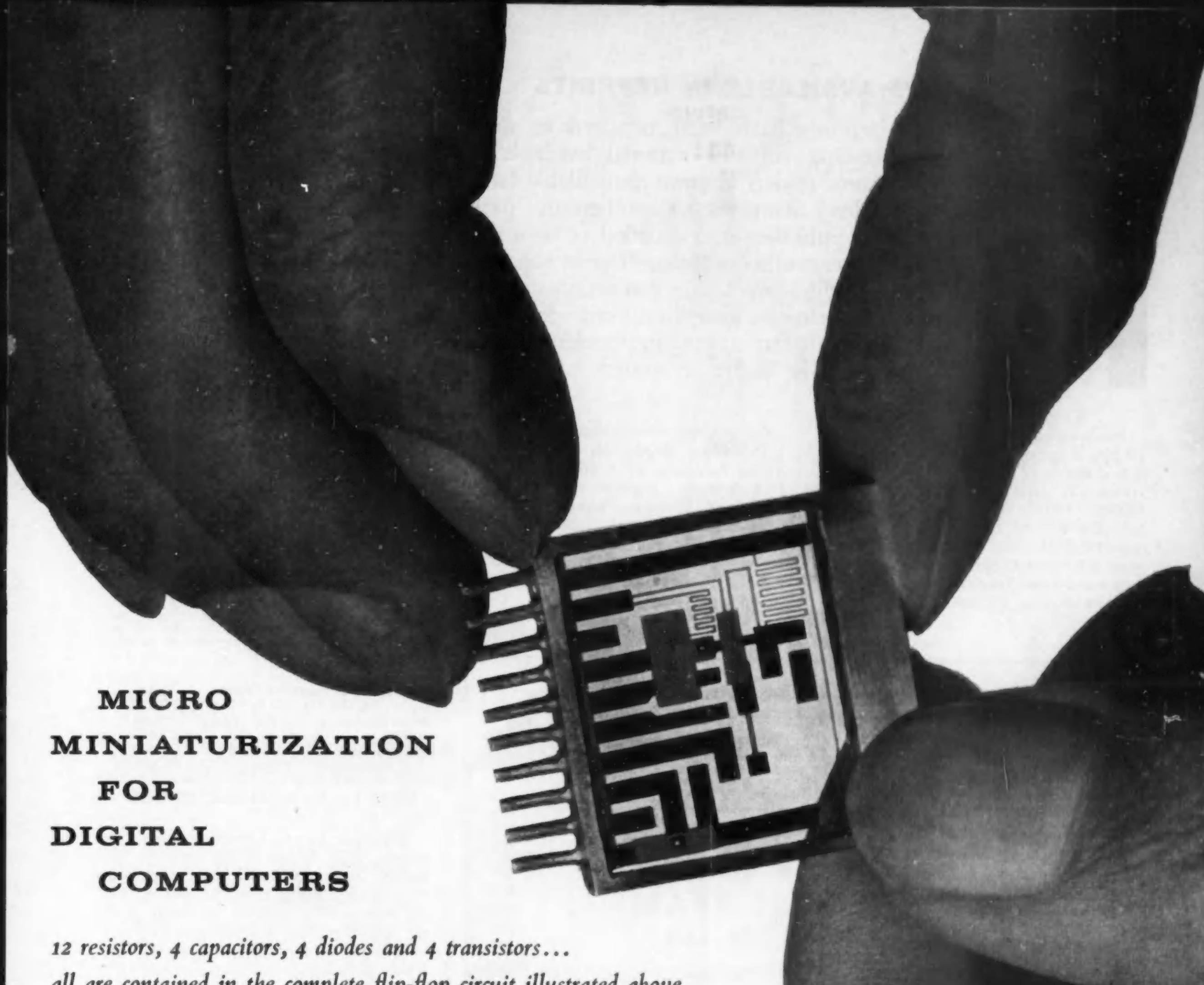
American Institute of Mining & Metallurgical Engineers, 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Ovens, and Raw Materials Conference, Jefferson Hotel, St. Louis April 6-8

Conference on Industrial Instrumentation & Control, sponsored by Armour Research Foundation, Illinois Tech campus, Chicago. April 14-15

Institute of Environmental Engineers, Third Annual Technical Meeting, LaSalle Hotel, Chicago April 22-24

MAY

American Institute of Electrical Engineers, Joint Conference on Automatic Techniques, Pike Congress Hotel, Chicago May11-13



MICRO MINIATURIZATION FOR DIGITAL COMPUTERS

12 resistors, 4 capacitors, 4 diodes and 4 transistors... all are contained in the complete flip-flop circuit illustrated above.

At the Hughes Research & Development Laboratories, dramatic reduction in component size is symbolic of the advances in the digital computer art...advances which are preparing the digital computer for its role as a system control in space.

In addition to developing new digital circuits and components, Hughes engineers are delving into other digital computer space mission tasks such as navigation guidance and control, communications processing and display, vehicle control, mission programming.

An intensive Hughes program in digital computer systems has created openings for creative engineers and physicists with degrees from accredited engineering universities in the following fields:

CIRCUIT and COMPONENT DEVELOPMENT: Digital Computer Analysis, Microcircuitry and Cryogenics, Solid State Physics, Magnetic Storage Devices.

SYSTEMS ENGINEERING: Closed-loop Digital Control, Digital Sensing and Conversion, Radar and Communications Information Processing, Inertial Navigation.

The salary structure for these personnel reflect the exceptional backgrounds required and the unusual challenge of the projects.

Inquire by writing directly to:
Dr. Allen Puckett, Associate Director
Systems Development Laboratories

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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

First-Hand Report on Control Inside Russia, November 1958, 16 pp. A team of 14 U. S. control engineers representing the American Automatic Control Council reports on the status of automatic control in Russia. Each expert gives impressions of progress in his field of interest based on visits to Russian user plants and research facilities. 40 cents.

Reprint Order Form

Reprint	Unit price	No ordered	Subtotal
Economics in Control	$0.50	......	......
Electronic Process Control Systems	$0.40	......	......
Report on Russian Control	$0.40	......	......
Calculating a Control Index	$0.30	......	......
Servo Design Techniques	$0.65	......	......
Flowmeters	$0.50	......	......
Applying Control Timers	$0.50	......	......
Control System Reliability	$0.20	......	......
Point-to-Point Positioning Systems—I, II & III	$1.50	......	......
Point-to-Point Positioning Systems—III	$0.40	......	......
Point-to-Point Positioning Systems—II	$0.50	......	......
Ready Reference Data File	$0.50	......	......
Servo Modulators	$0.65	......	......
The Uses of Digital Computers	$3 00	......	......
Analysis Instrumentation—II	$0.60	......	......
Analysis Instrumentation—I	$0.60	......	......
Basic Data on Process Control	$0.50	......	......
How to Stimulate Dead Time	$0.15	......	......
Power Amplifiers	$0.50	......	......
Static Switching Devices	$0.50	......	......
Automatic Logging Systems	$0.50	......	......
Automatic Machining—A View and a Preview	$0.50	......	......
A Systems Analysis Predicts Performance	$0.50	......	......
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Basic Digital Series			
Programming the Computer	$0.25	......	......

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Electronic Process Control Systems, November 1958, 16 pp. A staff report on the hottest area in materials processing control. Besides giving complete data on the six commercially available electronic process control systems (four of them were first announced at the 1958 ISA show), the article discusses the common denominators of all such systems and points out why user, consultant, and maker are interested in electronics. 40 cents.

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

Servo Design Techniques, 32 pp. A reprint of six related articles describing various electromechanical servo design techniques. Items include tachometer limiting, force-reflecting servos, calculating performance of drag-cup tachs, dual-mode servo compensation, applying packaged servo actuators, and cascading resolvers without amplifiers. 65 cents.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their charac-

teristics, and techniques for custom-designing controls for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed. 20 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems, 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.50.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—III, March 1958, 16 pp. Includes detailed descriptions of nine machine tool control systems. 40 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. Includes detailed descriptions of ten machine tool control systems. 50 cents.

Ready Reference Data Files, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical

Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors as low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

Automatic Machining—A View and a Preview, 24 pp. A quick look at some of the newer techniques that are being used to control machine tools. It deals primarily with recorded-information (numerical) control, discussing ways to automatically furnish machining instructions, ways to drive the tool, or workpiece, and ways to measure position and size. 50 cents.

A System Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

Digital Application Series. For those readers who would like to fill out incomplete sets of Application Series articles, the following are available as reprints 25 cents each:

- **Programming Scientific Calculators**—No. 5, May 1956, 6 pp.
- **Controlling a Process**—No. 9, December 1956, 5 pp.
- **Fitting the Digital Computer into Process Control**—No. 12, June 1957, 8 pp.

Basic Digital Series. For those readers who would like to fill out incomplete sets of Basic Digital articles, the following is available in reprinted form 25 cents:

- **Programming the Computer**—No. 12 March 1957, 6 pp.

EUROPEAN BITS

First computer designed in Poland has been completed under directions of the Polish Academy of Sciences. The vacuum-tube machine—it uses 500 tubes—can complete 800 arithmetic operations per sec.

•

Radar screens that can hold images for as long as 20 min have been developed by Ferranti, Ltd. A push-button controls showing of the stored image, which can be destroyed any time during the 20-minute period. Ferranti's device uses a new phosphor whose luminescence is visible only under infrared light. By throwing successive infrared light sources, of different wave lengths, on the screen, a rapid series of different images appear.

•

Russians have bought a British data logging system for use in production-control of its British-built tire plant, now under construction at Dnepropetrovsk. The system was developed by the British Iron & Steel Research Association and is being manufactured by Digital Engineering Co. It will collect hourly, from 500 points, such variables as number of batches of rubber produced, yards of tire fabric, tread parts, cured and uncured tires, and inner tubes.

In financial aid to education...

What Should Business Do Now?

Now that the federal government is entering the field, should business firms stop giving financial aid to our colleges and universities?

This question is now being discussed by business directors throughout the country. The discussion is prompted by the near-billion-dollar program of federal aid to education passed by Congress a few months ago. For if the federal government, with its access to billions in taxes, is assuming responsibility for the financial welfare of education, should not business get out of the way and let the government take over? This is the general way the question is being asked.

The answer is a resounding NO.

What The Federal Program Does

The new federal program makes it possible for the government to spend the imposing total of $900 million for aid to education over the next four years. There are still many loose ends in the program. But already it's quite clear what such funds will — and will not — do to help relieve the financial plight of our colleges and universities.

First of all, the program is not going to solve any financial problems in education overnight. The program is just barely underway. So far no money has actually been allocated, and Congress has appropriated only $40 million — less than 5% of the total.

More important, there is very little in the total program which will result in direct aid to colleges and universities. The program does set up fellowships to train college teachers. But most of the aid will eventually be channeled through the states to primary and secondary schools. The main focus of the program is education for national defense — strengthening science, mathematics and foreign languages in elementary and secondary schools, together with grants for counseling, testing and research.

The one big item for higher education is a $295 million student loan program, which will help needy students pay tuition and other fees. But tuition rarely covers the full cost to the college of educating a student. So the net result could well be an additional financial strain on our institutions of higher learning.

For the three most pressing financial needs — faculty salaries, scholarship grants and new plant and equipment—colleges and universities must still rely heavily on help from the business community. And it would indeed be a major

misfortune if the recent actions of the government put a blight on this growing and substantial support to higher education.

In the last ten years, business has expanded its financial aid to education by more than four fold. In 1948, contributions were only $24 million. In 1957, such aid reached an estimated $125 million. Moreover, corporations have been putting a larger proportion of their total charitable gifts into education. In 1950, the percentage was only 17%. By pre-Sputnik 1956, the share had already increased to 34%, according to figures recently released by the Council for Financial Aid to Education.

Why Business Must Help

The most compelling reason for increasing business aid to higher education — at an even faster rate—is that our colleges and universities desperately need financial help. It is that simple. Private contributions to higher education must average at least $400 million over the next ten years if our colleges are to meet rising operating costs and raise faculty salaries to decent levels. Despite the growth in business contributions, we are still well below that goal.

If our colleges cannot solve their mounting financial difficulties through voluntary help from business firms, alumni and communities — then it is to be expected that federal aid ultimately will be mobilized in a big way. In principle, if not in dollars, the 85th Congress has paved the way. Indeed, a large federal scholarship program was squeezed out of this year's legislation only in the course of last-minute compromises. And Arthur S. Flemming, Secretary of Health, Education and Welfare, has urged that the next session of Congress restore the scholarship program.

About any federal rescue operation for higher education, two things are quite clear:

(1) **Such aid will come too late to prevent irreparable harm resulting from the current shortage of funds.** The need for help is urgent and immediate.

(2) **With federal taxes taking over half of all corporate income, any federal program in the end will be financed in large part by the business community.**

An Opportunity

So, viewed narrowly, it is in the selfish interest of business firms to aid our colleges and universities now, rather than wait and be forced to pay later on. By doing so, they ensure that business will have a continuing supply of well-trained graduates. They take advantage of the tax laws for charitable contributions which mean the government in effect assumes more than half the cost of business aid to education. And they win gratitude for a voluntary and generous act.

Viewed in the broad public interest, the business community has an opportunity to perform a financial rescue mission in education which could well be the key to successful survival, not only of our present system of higher education, but also of the nation itself.

As previous editorials in this series have pointed out, a very small share of the net income of business firms — about 1% — would do the job. Certainly business must not be distracted from this opportunity by the new venture of the federal government in financial aid to education.

This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nation-wide developments. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

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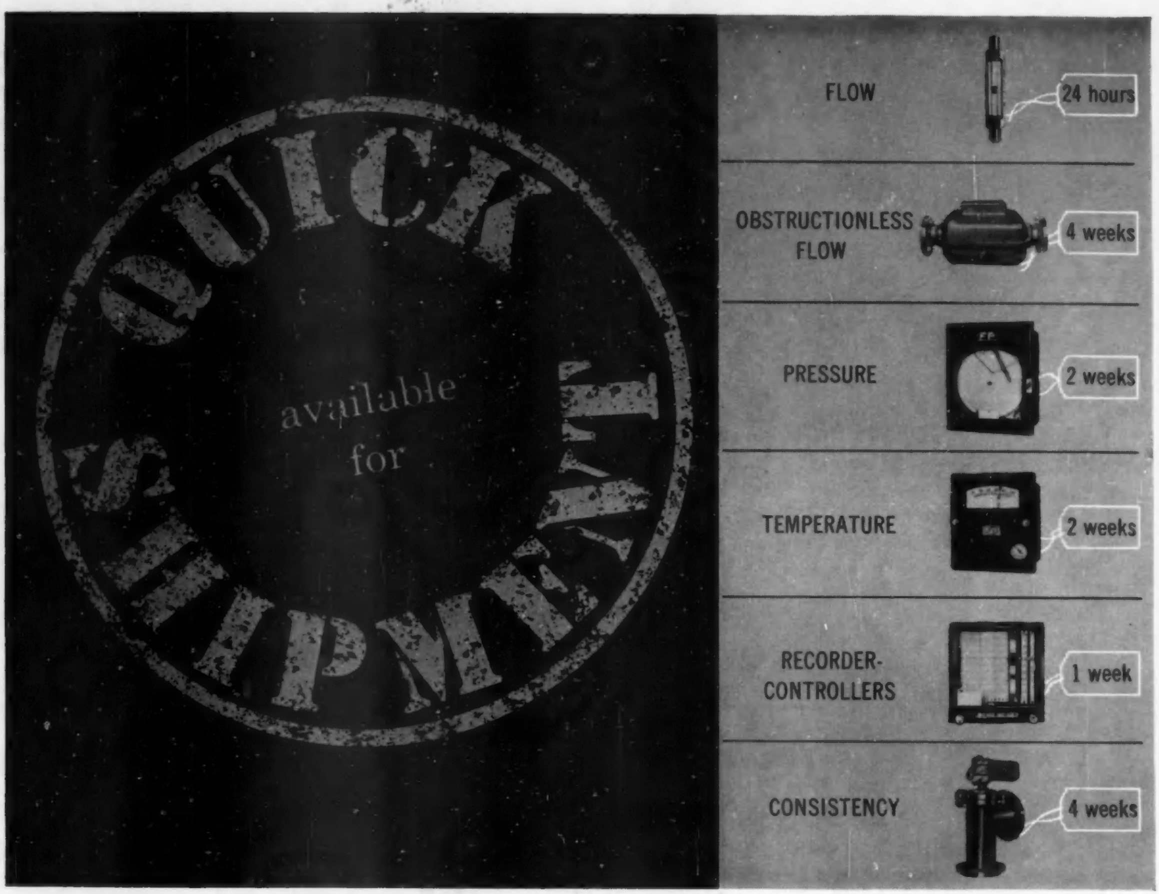

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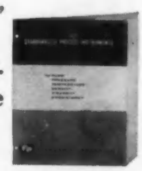

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